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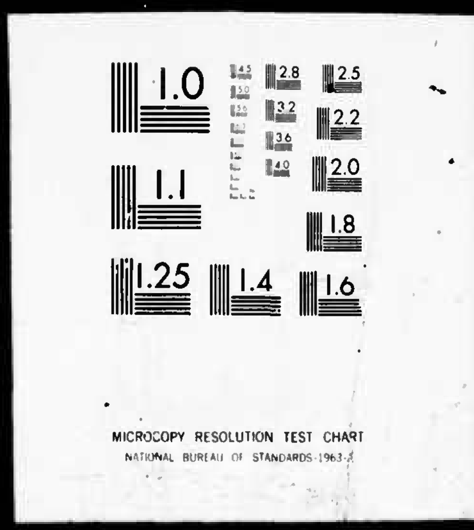

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Phase Report
October 1977

AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL SYSTEMS

GTE Sylvania, Inc.

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Trending	Digital DCS
Prediction	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study analyzes the DCS digital transmission system and requirements; defines the wideband digital (CPMAS) Communications Performance Monitoring and Assessment requirements; defines and evaluates CPMAS alternatives; recommends a wideband digital CPMAS approach; makes recommendations for the ATEC production; sets up a plan to demonstrate feasibility of wideband digital CPMAS approach (option phase), and makes recommendations for ATEC research and development programs. next page

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The Digital Transmission System Model provides multi-link routes, a variety of station types (e.g., nodal station, branching repeater station and terminal station) transmission equipments (e.g., Radio, Key Generator, Multiplexers, Submultiplexers and service channel multiplexers), and terminations (e.g., 4 kHz (PCM derived), async digital channels, digital groups, and 16 kb/s digital subchannels). The radios used for digital transmission include DRAMA-type digital radio; FM radio with Digital Applique Unit; and FM radio with T1-4000 multiplexer baseband section (FKV).

It was found that channel estimation is the best single performance assessment technique. Also, channel estimation plus DRAMA BITE is the best combined approach and is more cost effective than channel estimation alone. For partial response systems, it is recommended that format violation be used in addition to channel estimation and DRAMA BITE.

It is shown that failure prediction can greatly increase the equipment mean time between failures. The parameters recommended for trending are transmitted signal power, signal-to-distortion ratio, and signal-to-noise ratio.

A Hybrid Sequential/Signature fault detection/isolation approach is proposed.

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TABLE OF CONTENTS

Section		Page
1.	INTRODUCTION	1
2.	STUDY SUMMARY	3
2.1	Background	3
2.2	DCS Digital Transmission System	4
2.3	CPMAS Requirements	9
2.4	CPMAS Alternatives	12
2.4.1	Performance Assessment Alternatives	12
2.4.2	Trend Analysis Alternatives	13
2.4.3	Fault Detection/Isolation	16
2.4.4	Telemetry	20
2.5	Technical Control Man-Machine Interface	26
2.6	Recommended CPMAS Approach	27
2.7	CPMAS Feasibility Demonstration Plan (Option Phase)	33
2.8	Future Related Research and Development	39
3.	DCS DIGITAL TRANSMISSION SYSTEM	42
3.1	Digital Transmission System Model	42
3.1.1	Radio Systems	47
3.1.2	Satellite Terminal Interface	47
3.1.3	Nodal Station Model	51
3.1.4	Sensitivity Analysis Parameters	51

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TABLE OF CONTENTS (Continued)

Section		Page
4.	CPMAS REQUIREMENTS	54
4.1	DCS Availability and Performance Requirements	54
4.1.1	DCS Performance Objectives	54
4.1.2	CPMAS Considerations	57
4.2	CPMAS Effectiveness	60
4.3	CPMAS Functional Requirements	63
4.3.1	CPMAS Description	65
4.3.2	Sector/Nodal/Station Control Interoperability	67
4.3.3	Nodal Control Subsystem	70
4.3.4	CPMAS Subsystems Functional Requirements	71
5.	CPMAS ALTERNATIVES	80
5.1	Performance Assessment Alternatives	81
5.1.1	Equipment Failure Analysis	81
5.1.2	Description of Techniques	91
5.1.3	Performance Assessment Technique Comparison	101
5.1.4	Recommendations	107
5.2	Trend Analysis Alternatives	108
5.2.1	Trend Analysis Benefits	108
5.2.2	Parameters to be Trended	109
5.2.3	Trend Analysis Methods	114
5.2.4	Trend Analysis Technique Comparison	123
5.2.5	Recommendations	131
5.3	Fault Detection/Isolation	133

TABLE OF CONTENTS (Continued)

Section		Page
5.3.1	Description of General Fault Analysis Techniques	134
5.3.2	Candidate Approach to Fault Analysis	145
5.3.3	Signatures in Fault Analysis	151
5.3.4	Ancillary Functions in Fault Analysis	160
5.3.5	Fault Isolation Examples	177
5.3.6	Recommendations	194
5.4	Telemetry	196
5.4.1	Wideband Digital CPMAS Data Coding Alternatives	200
5.4.2	Nodal Control - Station Control Telemetry	204
5.4.3	Recommendations	208
6.	TECHNICAL CONTROL MAN-MACHINE INTERFACE	212
6.1	Fault Summary Display	215
6.2	Nodal Control Displays - Fault Example 1	220
6.3	Nodal Control Displays - Fault Example 2	224
7.	DESCRIPTION OF RECOMMENDED CPMAS APPROACH	231
7.1	CPMAS System Description	231
7.2	CPMAS Subsystem Description	236
7.2.1	CPMAS-D	238
7.2.2	Communications Interface Set (CIS)	238
7.2.3	CPMAS-NCS	241
7.2.4	Station Control Position Function	241
7.3	CPMAS Hardware Description	241
7.3.1	CPMAS Hardware Description	241

TABLE OF CONTENTS (Continued)

Section		Page
7.3.2	Hardware Designs and Recommendations	244
7.4	CPMAS Software Description	259
7.4.1	Introduction	259
7.4.2	CPMAS-NCS Software Functional Description	260
8.	RECOMMENDATIONS FOR ATEC PERFORMANCE SPECIFICATION	342
8.1	Multiplexer Monitoring	342
8.2	Automated Equipment Switching	342
8.3	Displays	343
8.4	WDMS Data	343
8.5	Telemetry Rates	343
8.6	Communications Interface Set	343
9.	CPMAS FEASIBILITY DEMONSTRATION (OPTION PLAN)	345
9.1	Program Description	347
9.2	Hardware Description	359
9.2.1	Test Processor Subsystem	359
9.2.2	Channel Estimator (CE)	367
9.2.3	Wideband Digital Monitoring Set (WDMS)	367
9.3	Software Description	368
9.4	Test Program	381
9.4.1	Site Surveys	381
9.4.2	In-House Tests	381
9.4.3	CONUS Testing	382
9.5	Program Plan	387

TABLE OF CONTENTS (Continued)

Section		Page
9.5.1	Work Breakdown Structure	389
9.5.2	Make/Buy Plan	391
10.	RECOMMENDED RESEARCH AND DEVELOPMENT AREAS	394
10.1	Automatic Digital Network Control	394
10.2	Analysis of Restored/Alternate Routing Procedures in an Automatic Environment	397
10.3	Electronic Counter Counter Measures (ECCM)	399
10.4	Programmable Multiplexer Design and Development	399

APPENDICES

Appendix		Page
A.	DIGITAL TRANSMISSION EQUIPMENT - UNIT DESCRIPTIONS	400
A.1	Second Level Multiplexer	401
A.1.1	Data Rates	401
A.1.2	Framing	401
A.1.3	Synchronous and Asynchronous Comparison	404
A.1.4	Redundancy	404
A.1.5	Alarms	404
A.1.6	Pseudo-Random Generator Detector	408
A.2	First Level Multiplexer	408
A.2.1	Data Rates	410
A.2.2	Framing	410
A.2.3	Alarms	411
A.3	Submultiplexer	415
A.3.1	Applications	415
A.3.2	Data Rates	415
A.3.3	Structure and Alarms	417
A.3.4	Fault Isolation	419
A.4	Bulk Encryptor	419
A.5	Radio Systems	419
A.5.1	Digital Radio	424
A.5.2	Analog Radio Systems	439
A.6	Group Data Modem (AN/USC-26)	453
A.6.1	Data Rates	453

APPENDICES (Continued)

Appendix		Page
A.6.2	Alarms	453
A.7	AN/GSC-24(V) Asynchronous Time Division Multiplexer	456
A.7.1	Data Rates	456
A.7.2	Diagnostics and Alarms	457
A.8	MD-920/G Modem	457
A.8.1	Data Rates	458
A.8.2	Performance Monitoring	458
B.	CPMAS EFFECTIVENESS CALCULATIONS	459
B.1	First Level Multiplexer	459
B.2	Crypto/Crypto By-Pass	462
B.3	Second Level Multiplexer	462
B.4	Radio	466
B.5	Propagation Media	469
B.6	CPMAS Related Variable	469
C.	RELIABILITY/AVAILABILITY/MAINTAINABILITY ANALYSIS	471
C.1	Summary	471
C.2	Reliability Prediction	471
C.3	Availability Prediction	476
C.4	Preliminary Maintenance Concept	479
D.	NODAL AREA PARAMETER DATA BASE	480
E.	FAULT DETECTION/ISOLATION PROCESSING TIME ESTIMATES	486
F.	ESTIMATE OF NUMBERS OF SIGNATURES FOR DRAMA EQUIPMENTS	491

APPENDICES (Continued)

Appendix		Page
G.	DNC FUNCTIONAL DESCRIPTION	497
G.1	Digital Control Element (DCE) Description	497
G.1.1	Interface and Reassignment Group A (IRGA)	497
G.1.2	Interface and Reassignment Group B (IRGB)	501
G.1.3	Common Equipment Group (CEG)	503
G.2	DCE CONTROL	505
G.3	OPERATIONAL ALGORITHMS	507
G.3.1	Man/Machine Interface	507
G.3.2	Functional Algorithms	508
G.3.2.1	Static Functional Algorithms	508
G.3.2.2	Dynamic Functional Algorithms	509
G.3.3	Fault Control	512
G.3.3.1	Hardware Failures	512
G.3.3.2	Software Failures	513
G.3.4	Initialization and Recovery	514
G.4	SYNCHRONIZATION	515
G.4.1	Master Frame Synchronization	515
G.4.2	DCE Timing	517
	ACRONYMS	520

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Wideband Digital CPMAS Study Program	2
2-1	Digital Transmission System Model Nodal Area	5
2-2	Multilink Subnetwork	6
2-3	Fault Detection/Isolation Sequence	19
2-4	Inter-Relation of Functions in Fault Analysis	21
2-5	CPMAS System Block Diagram	22
2-6	Model Telemetry Network	24
2-7	Telemetry Communications	25
2-8	Fault Display Hierarchy	28
2-9	CPMAS Hardware Element Family Tree	32
2-10	CPMAS Operational Software Family Tree	34
2-11	Functional CPMAS Evaluation Model	36
2-12	CPMAS Evaluation Model	37
2-13	Evaluation Model for Field Test	38
3-1	Digital Transmission System Model (Nodal Area)	43
3-2	Multilink Subnetwork	45
3-3	Histogram of Station Radio Quantities	46
3-4	Digital and DAU/FM Radio Links	48
3-5	FKV MUX/Radio System	49
3-6	Satellite Terminal Interface	50
3-7	Nodal Station Model	52
4-1	Reference Digroup	58
4-2	Reference Channels (Voice and Data)	59

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
4-3	Effect of Unalarmed Failures Upon Channel Unavailability	64
4-4	CPMAS Functions	66
4-5	CPMAS for Digital Transmission	66
4-6	Sector/Nodal/Station Interoperability	68
5-1	DRAMA Radio Functional Block Diagram	89
5-2	Pseudo Error Counter Performance Assessment Technique	95
5-3	Communications System with Channel Estimation	97
5-4	Mean Parameter Estimation Error Convergence	99
5-5	Bit Error Rate Estimation Accuracy	106
5-6	Trend Analysis Benefits	110
5-7	Forecast Accuracy for Trend Analysis Techniques (Data Age=25 Samples)	127
5-8	Forecast Accuracy for Trend Analysis Techniques (Data Age=50 Samples)	128
5-9	Forecast Accuracy for Trend Analysis Techniques (Data Age=100 Samples)	129
5-10	Trend Analysis Storage Requirements	130
5-11	Sequential Processing Approach	135
5-12	Fault Detection via Sequential Processing	136
5-13	Illustration of Relationship $E=2^N$	137
5-14	Fault Analysis Using Tree Approach	138
5-15	Parallel Processing Approach	139
5-16	Signatures of Common Fault Conditions	140
5-17	Attributes of Fault Analysis Processing Techniques	141

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
5-18	Inter-Relation of Functions in Fault Analysis	146
5-19	Fault Detection/Isolation Sequence	147
5-20	Fault Detection Process at Node	148
5-21	Fault Severity Assessment, Approach 1	152
5-22	Fault Severity Assessment, Approach 2	153
5-23	Fault Detection Message Components	154
5-24	Fault Isolation Work Queue Message Input Function	155
5-25	Structure for Fault Isolation, Excluding Correlation Jumps	156
5-26	Isolation Procedure for an Equipment	157
5-27	Information Contained in a Signature Vocabulary Entry	158
5-28	Attributes of Recommended Hybrid Approach	159
5-29	Fault Severity Assessment Signatures KG-81 Trunk Encryption Device	161
5-30	Fault Severity Assessment Signature for AN/FRC 163 Radio Set	162
5-31	Fault Severity Assessment Signature for 2nd Level MUX TD 1193	163
5-32	Fault Severity Assessment Signature for 1st Level MUX TD 1192	164
5-33	Fault Isolation Signature for Power Generation System	165
5-34	Fault Isolation Signature for RF Distribution System	166
5-35	Fault Isolation Signature for Radio Set AN/FRC 163	167

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
5-36	Fault Isolation Signature for KG-81 Trunk Encryption Device	168
5-37	Fault Isolation Signature for 2nd Level MUX TD 1193	169
5-38	Fault Isolation Signature for 1st Level MUX TD 1192	170
5-39	Actions for Operator Interface	172
5-40	Actions on Operator Initiated Fault Isolation	173
5-41	Sequence of Actions Corresponding Inter-Nodal Fault Isolation	175
5-42	Actions in Response to an Unresolved Fault	176
5-43	Actions in Response to Resolution of a Previously Unresolved Fault	178
5-44	Fault Isolation/Detection Example	179
5-45	Fault with Sympathetic Alarms	182
5-46	Fault Analysis Example 3	189
5-47	CPMAS System Block Diagram	197
5-48	Model Telemetry Network	198
5-49	Telemetry Communications	199
5-50	CPMAS Fault Transmit Time versus Telemetry Channel Bit Rate	201
5-51	CPMAS Fault Transmit Time versus Telemetry Channel Bit Rate	202
5-52	CPMAS Fault Transmit Time versus Telemetry Channel Bit Rate	203
5-53	Telemetry Data Coding	205
5-54	Fault Detail Display	206

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
5-55	NCS Fault Display Transmit Time versus Telemetry Channel Bit Rate	207
5-56	Communications Interface Set Design Alternatives	209
6-1	CPMAS System Block Diagram	213
6-2	Fault Display Hierarchy	214
6-3	Nodal Control Fault Summary Display 1	216
6-4	Digital Transmission System Model Section	218
6-5	Fault Example 1	221
6-6	Fault Summary Display 2	222
6-7	Fault Detail Display 1	223
6-8	Fault Example 2	225
6-9	Fault Detail Display 2	226
6-10	Fault Detail - Equipment Display 1	227
6-11	Fault Detail - Equipment Display 2	228
6-12	Detail Path Description Display	229
7-1	CPMAS Hierarchy	232
7-2	CPMAS System Block Diagram	235
7-3	CPMAS-D Functional Block Diagram	239
7-4	CIS Functional Block Diagram	240
7-5	CPMAS-NCS Functional Block Diagram	242
7-6	Station Control Position Functional Block Diagram	243
7-7	CPMAS-NCS Conceptual Block Diagram	245
7-8	CPMAS-D Unit Conceptual Block Diagram	248

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
7-9	DCS Digital Transmission System Model	250
7-10	CPMAS-D Cost vs. Monitor Point Quantity	251
7-11	CPMAS-D Branching Repeater Cost	252
7-12	CPMAS-D Terminal Station Cost	253
7-13	CPMAS-D Nodal Station Cost	254
7-14	Station Control Position Conceptual Block Diagram	257
7-15	CIS Conceptual Block Diagram	258
7-16	CPMAS Operational Software Family Tree	262
7-17	NCS Front End Processor Configuration 1	264
7-18	NCS Front End Processor Configuration 2	265
7-19	NCS Front End Processor Software Functions	266
7-20	Estimated Processing Time vs. Baud Rate Using Intel 8080	269
7-21	Estimated Processing Time vs. Baud Rate Using DEC LSI-11	270
7-22	Estimated Processing Time vs. Baud Rate Using DEC PDP 11/34	271
7-23	Total Effective Throughput Rate for NCS Front End Processor	272
7-24	CPMAS-NCS Software Flow Diagram	275
7-25	Data Base Structure for CPMAS Data	286
7-26	CPMAS-D Functional Interface	296
7-27	CPMAS-D Software Tree	298
7-28	Functional Flow of CPMAS-D Scan Cycle	300
7-29	Functional Flow of CPMAS-D Exception Processing	302

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
7-30	Task (Function) Control	307
7-31	Station Control Radio Status Display	311
7-32	Data Block Format	321
7-33	CIS Operation	329
7-34	CIS Software Family Tree	330
7-35	Station Control Data Storage vs. Number of Radio Systems	334
7-36	CPMAS-D Storage vs. Number of Radio Systems at Nodal Station	335
7-37	CPMAS-D Data Storage vs. Number of Radio Systems at Terminal Station	337
7-38	CPMAS-D Data Storage vs. Number of Radio Systems at Branching Repeater	338
7-39	CPMAS-D Data Storage vs. Number of Radio Systems at Nodal Station	339
7-40	CPMAS-D Scan Time vs. Number of Radio Systems at Nodal Station	341
9-1	Functional CPMAS Evaluation Model	348
9-2	CPMAS Evaluation Model	349
9-3	CPMAS Evaluation Model for Field Test	349
9-4	Test Processor Subsystem	350
9-5	CE Evaluation Model for Field Test	355
9-6	Test Processor Subsystem	360
9-7	Data Path Block Diagram Transmission System Simulator Interface	361
9-8	Control Block Diagram Transmission System Simulator Interface	362
9-9	Data Path Block Diagram Baseband Simulator Interface	364

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
9-10	Control Block Diagram Baseband Simulator Interface	365
9-11	Test Processor Subsystem	366
9-12	CE Block Diagram	369
9-13	CE Performance Assessment Module	370
9-14	W/B Monitoring Set Block Diagram	371
9-15	W/B Monitoring Set	372
9-16	Test Processor Family Tree	373
9-17	CPMAS-D Test Display	377
9-18	WDMS Family Tree	379
9-19	Simplified Map: CTA to Site Sibyl Microwave Link	384
9-20	CPMAS Evaluation Model for Field Test	385
9-21	CE Evaluation Model for Field Test	386
9-22	Option Phase Development & Test Program	388
9-23	CDRL Summary	390
10-1	Digital Network Control Application Summary	395
10-2	Digital Network Control Function Diagram	396
10-3	Digital Network Control Field Test Model	398
A-1	TD-1193 Second-Level Multiplexer	402
A-2	TD-1192 First-Level Multiplexer	409
A-3	TDM-1251 Submultiplexer Block Diagram	416
A-4	Digital Transmission System	425
A-5	DRAMA Radio Configuration for Space and Frequency Diversity	430

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
A-6	DRAMA Radio Functional Block Diagram	435
A-7	Types of Analog Radio Systems for Digital Transmission	440
A-8	AN/FRC-162 Functional Block Diagram	444
A-9	Digital Applique Unit (DAU) Block Diagram	447
A-10	T1-4000 Multiplexer Block Diagram	451
A-11	AN/USC-26 Group Data Modem Block Diagram	455
C-1	RAM Analysis Process	472
C-2	CPMAS System Reliability Block Diagram (Nodal Station/8 Radios)	474
C-3	CPMAS System Reliability Block Diagram (Repeater Station)	475
C-4	CPMAS System Availability Block Diagram (Nodal Station/8 Radios)	477
C-5	CPMAS System Availability Block Diagram (Repater Station)	478
D-1	Relation of Equipment Status Messages Within a Site Word for a Terminal Station Configuration	482
D-2	Relation of Equipment Status Messages Within a Site Word for a Terminal Station Configuration	483
D-3	Formatting of Data Base	485
G-1	DCE - Station Configuration	498
G-2	Interface and Reassignment Group A	499
G-3	Interface and Reassignment Group B	502
G-4	Common Equipment Group	504

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
G-5	DCE Control Hierarchy	506
G-6	Reroute Scenario	510
G-7	Master Timing Unit Buffer Requirement	519

LIST OF TABLES

Table		Page
2-1	Nodal Area Model Station Quantities	8
2-2	Model Sensitivity Parameter Summary	8
2-3	CPMAS Performance (Digroup Unavailability)	10
2-4	CPMAS Performance (Channel Unavailability)	11
2-5	Digital Radio Performance Assessment Technique Selection	14
2-6	Trend Analysis Parameter Selection	15
2-7	Trend Analysis Technique Selection	17
2-8	Functional Units for Digital Transmission	30
2-9	Digital Network Control Application Summary	40
3-1	Nodal Area Model Station Quantities	46
3-2	Nodal Area Sensitivity Parameters	50
3-3	Nodal Station Model Characteristics	52
3-4	Station Sensitivity Parameters	53
3-5	Model Sensitivity Parameter Summary	53
4-1	Performance Objectives for the Digital DCS Transmission System	56
4-2	CPMAS Performance (Digroup Unavailability)	61
4-3	CPMAS Performance (Channel Unavailability)	62
5-1	Radio Transmitter Induced Degradations	84
5-2	Radio Receiver Induced Degradations	85
5-3	MUX-DEMUX Induced Degradations	86
5-4	Propagation Media Induced Degradations	87
5-5	DRAMA Radio Failure Investigation Results	90

LIST OF TABLES (Continued)

Table		Page
5-6	Digital Radio Performance Assessment Technique Selection	102
5-7	Performance Assessment Parameters	104
5-8	Trend Analysis Parameter Selection	111
5-9	Trend Analysis Technique Selection	125
6-1	Equipment Terminal Fault Location Designations	219
7-1	CPMAS Unit Function Allocations	237
7-2	NCS Front End Processor Subfunctions	267
7-3	Technical Control Function Commands	279
7-4	Preliminary CPMAS Data Base Estimate - Words	283
7-5	Preliminary CPMAS Data Base Estimate - Equipment	285
7-6	Programming Language Trade-Offs	292
7-7	Programming Language Characteristics	294
7-8	Station Controller Man/Machine Keyboard Command/Request	314
9-1	Characteristics of Test Processor Subsystem	354
9-2	Make/Buy Plan Development/Test Phase - CPMAS	392
9-3	Make/Buy Plan Development/Test Phase - DNC	393
A-1	Second-Level Multiplex Terminal	403
A-2	Second-Level Multiplex Monitor/Alarm Functions	405
A-3	First-Level Multiplexer Alarm Operations	412
A-4	Submultiplexer Alarm Indicator Operation	420
A-5	Components of DRAMA Radio Sets	427
A-6	DRAMA Radio Operational Capabilities	427

LIST OF TABLES (Continued)

Table		Page
A-7	DRAMA Radio Interfaces	428
A-8	Candidate Radio Modulation Techniques	431
A-9	Performance Assessment Techniques for Various Modulation Methods	434
A-10	DRAMA Radio Typical CPMAS Monitor/Test Points	436
A-11	Functions and Implementation of Two PR-Class Codes	442
A-12	AN/FRC-162 Monitor/Test Points	446
A-13	DAU Typical CPMAS Monitor/Test Points	449
A-14	T1-4000 Monitor/Test Points	454
B-1	First Level Multiplexer Failure Analysis	460
B-2	Crypto/Crypto By-Pass Failure Analysis	463
B-3	Second Level Multiplexer Failure Analysis	464
B-4	Radio Failure Analysis	467
C-1	Equipment Reliability Analysis Summary	473
G-1	DCE T1 Frame Synchronization Performance	517

EVALUATION

The value and significance of this work is that it presents a full spectrum analysis of performance assessment techniques for the digital DCS derived from the DCA requirements base. Three promising techniques are strongly recommended for further development and verification under the development phase of this contract. These are: (1) Adaptive channel estimation; (2) Digital hybrid (sequential/signature) fault detection/isolation; and (3) Trending for prediction. Outputs of this development effort will be applied to the ESD ATEC prediction program and related DCA/DCS System Control requirements.

This effort supports thrust R4A "Network Management Control", Subthrust "System Control and TPO IV", "Communications for Command and Control".

Charles N. Meyer

CHARLES N. MEYER
Project Engineer

SECTION I
INTRODUCTION

GTE Sylvania, Eastern Division, is pleased to submit this final report for the Automated Performance Monitoring and Assessment for DCS Digital Systems Program (also referred to as the Wideband Digital CPMAS Study). This study was performed for the Rome Air Development Center under Contract F30602-76-C-0433 during the six (6) month period November, 1976 to April, 1977. The analyses, results, and conclusions contained herein are in accordance with the objectives of the Statement of Work tasks and address the requirements, benefits, alternatives, and implementation of CPMAS for DCS digital transmission systems.

The Wideband Digital CPMAS study program is outlined in Figure 1-1. During the study DCS Digital Transmission System equipments and system requirements were analyzed to determine wideband digital CPMAS requirements. Based upon these CPMAS requirements, design alternatives for the Wideband Digital CPMAS were defined and evaluated to derive a recommended CPMAS approach. Results of the study included: (1) Recommendations for inclusion in the ATEC specification, (2) A feasibility evaluation/demonstration plan for evaluating selected portions of the recommended CPMAS approach, and (3) recommendations for automated technical control related research and development programs.

Technical discussions, approaches, alternatives, and recommendations for wideband digital CPMAS are presented in this report. In order to clearly present these results, this report is organized as follows:

a. Section 1 - Introduction
b. Section 2 - Study Summary
c. Section 3 - Presents the Digital Transmission System Model that was used as a framework for CPMAS analyses.
d. Section 4 - Discusses the DCS digital transmission system requirements and the resultant CPMAS requirements.

e. Section 5 - Describes and evaluates design alternatives for the wideband digital CPMAS.

f. Section 6 - Describes technical control man-machine interface results including nodal control displays

g. Section 7 - Presents the recommended wideband digital CPMAS approach which is based upon the analysis and conclusions of this study.

h. Section 8 - Describes the recommendations that can be incorporated directly into the ATEC Performance Specification.

i. Section 9 - Describes the wideband digital CPMAS feasibility/demonstration plan for the CPMAS Option Phase.

j. Section 10 - Summarizes the recommended research and development programs for Automated Technical Control.

k. Appendices A through G - Detailed analyses and/or reference data used in this study.

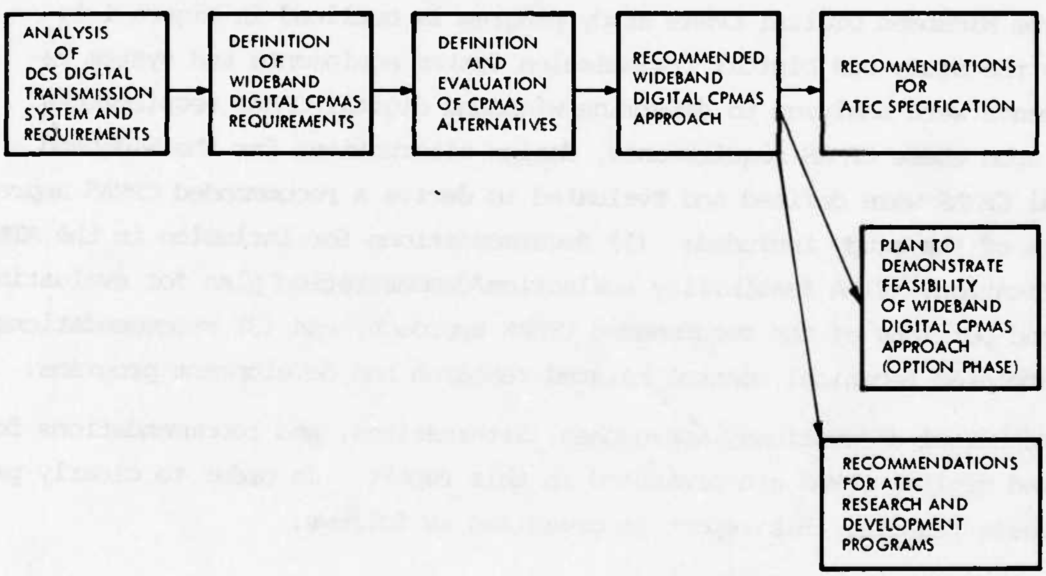

FIGURE 1-1. WIDEBAND DIGITAL CPMAS STUDY PROGRAM

SECTION 2

STUDY SUMMARY

This section summarizes the results of the CPMAS Study Phase. Background for the CPMAS program is briefly reviewed in Section 2.1. Sections 2.2 through 2.8 summarize the major topics of the CPMAS Study. These major topics include:

(1) DCS Digital Transmission System
(2) CPMAS Requirements
(3) CPMAS Alternatives and Their Evaluation
(4) Technical Control Man-Machine Interface for CPMAS
(5) Recommended CPMAS Approach
(6) CPMAS Feasibility Demonstration Plan for the CPMAS Option Phase
(7) Recommended ATEC Research and Development Areas.

2.1 Background

Evolution of the Department of Defense (DOD) Communications from analog systems through a hybrid (analog/digital) configuration to an all-digital posture is a transitional process which is expected to span the next two decades. Planning and development of effective technical control capabilities to efficiently manage communications resources is underway at this time. The constantly changing Defense Communications System (DCS) configuration, particularly the replacement of, or additions to the current Frequency Division Multiplex (FDM) network by digital systems, demand that R&D be accomplished to develop the technology to provide a responsive, automated, digital tech control capability.

The analog Defense Communications System (DCS) is evolving toward a hybrid analog/digital system. Subscribers are presently using their access circuits to transmit digital data, in quasi analog form, at data rates as high as 9600 bps. System upgrades have been approved, e.g., Frankfurt-Koenigstuhl-Vaihingen (FKV) and Digital European Backbone (DEB) segments of the Defense Communications System in Europe, that will replace the FDM equipments with Pulse Code Modulation (PCM) and Time Division Multiplex (TDM) equipments and introduce new microwave radio (MW) equipment, such as is planned under the Digital Radio and Multiplexer acquisiton (DRAMA

at selected terminals. Those upgrades will result in digital, as well as analog, signals in the technical control area. Therefore, to be responsive to the monitoring and performance assessment requirements of this imminent hybrid DCS, including its all-digital segments, the Automated Performance Monitoring and Assessment for DCS Digital Systems (CPMAS) Study was undertaken by GTE Sylvania under contract to Rome Air Development Center, Griffiss Air Force Base, New York.

2.2 DCS Digital Transmission System

The digital transmission equipment which makes up the digital portions of the DCS includes the DRAMA radio and multiplex equipment, Digital Applique Unit (DAU)/FM radio equipment, Frankfurt-Koenigstuhl-Vaihingen (FKV) radio and multiplex equipment, satellite terminal interface equipment, encryption equipment and the group data modem.

A digital transmission system model was designed to provide a framework for CPMAS analyses and designs. The digital transmission system model is based upon the planned DCS digital transmission system for Europe, government documents describing DCS digital transmission plans (e.g., DCEC TR 12-76, DCEC TR 3-74) and the Automated Technical Control System Description. The model provides a digital transmission system which includes a nodal control area, a large nodal station, terminal and repeater stations, a satellite terminal interface and several radio system alternatives. The model is sized to ensure that CPMAS designs can meet all requirements placed upon them when they are applied to any portion of the DCS Digital Transmission System. The model includes multi-link routes and various terminations (e.g., 4 kHz (PCM derived), asychronous digital channels, digital groups, and 16 kb/s digital subchannels).

The digital transmission system model shown in Figure 2-1 is a nodal area model which includes the different network characteristics and station types encountered in the planned DCS digital transmission system. Figure 2-2 is a diagram of the multi-link subnetwork which is used to make up the Nodal Area/network model. Shown specifically is the DRAMA configuration. The CPMAS study considered the DRAMA, DAU/FM, and FKV radio configurations. Four of these subnetworks are included in the nodal area model of Figure 2-1,

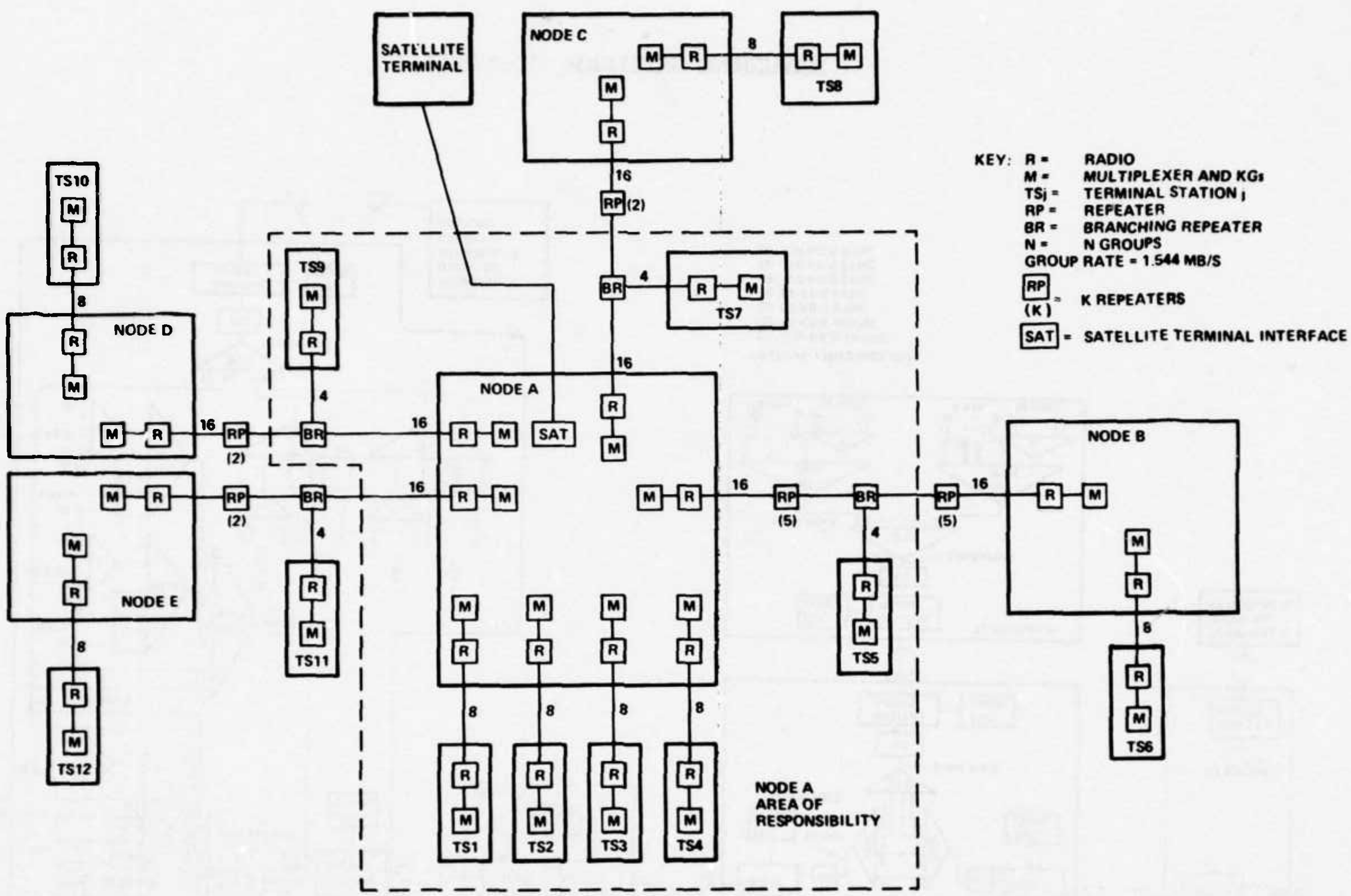

FIGURE 2-1. DIGITAL TRANSMISSION SYSTEM MODEL NODAL AREA

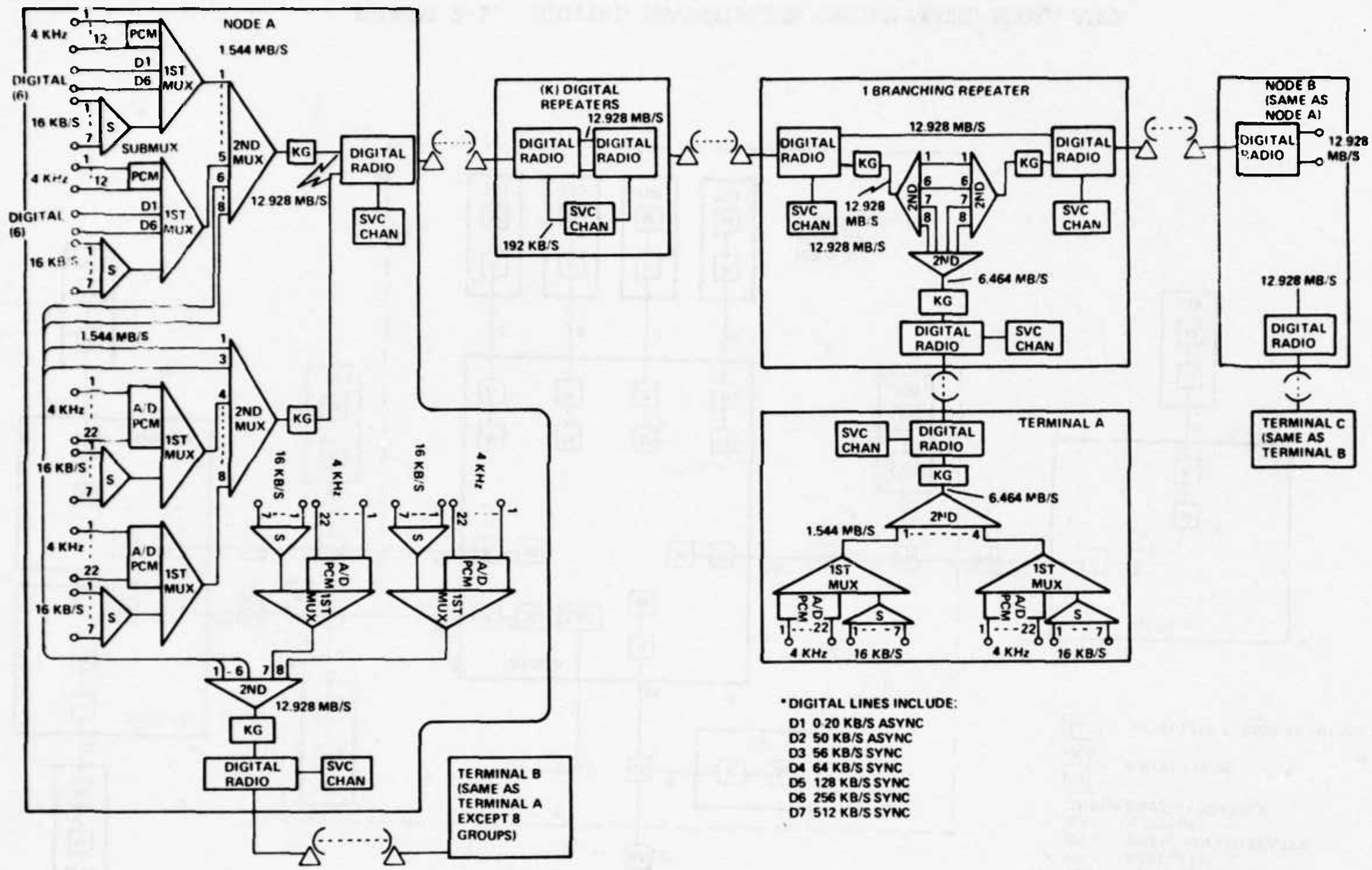

FIGURE 2-2. MULTILINK SUBNETWORK

to provide a model which will ensure that CPMAS deisgns meet the requirements placed upon them when applied to the DCS digital transmission system.

In the nodal area model of Figure 2-1, a nodal area of responsibility is defined by a dashed line. This particular nodal area, which is the responsibility of nodal control, has sixteen stations. The quantity of each station type in the nodal area is given in Table 2-1.

The digital transmission system model includes three different types of radio systems, namely the DRAMA-type digital radio, the FM radio with Digital Applique Unit and the FKV radio. The multiplex and encryption equipments are the same for both the DRAMA and FM/DAU radio systems since each radio can accept the same mission bit stream bit rate. These radio systems can transmit/receive two 12.9-megabit-per-second bit (Mb/s) streams.

The FKV system uses the T1/4000 second level Multiplexer, CY/104 first level (PCM) Multiplexers, and T1WB1 Digital Multiplexers. The FKV radio baseband signal is limited to 12.6 Mb/s and cannot directly replace all radios in the transmission system model. Comparative analyses (Section 7) for the FKV radio systems performed in the study adjusted radio and multiplex quantities to achieve a fair comparison of the FKV, DRAMA and FM/DAU radio systems.

The nodal area model contains 15 links and 4 interface links which terminate at another nodal area. The resulting number of radios within the nodal area model is 34. Sensitivity analyses were performed for nodal area radio quantities up to 128 radios. The ATEC System Description specifies a maximum of 64 links for a nodal area which implies a maximum of 128 radios.

The satellite terminal interface is a planned cable interface to the satellite terminal station. The satellite terminal interface multiplexers include the DRAMA first level multiplexer and the AN/GSC-24 second level multiplexer. A microwave radio link interface to the satellite terminal is also possible and would be identical to the terrestrial radio links already included in the transmission system model.

Many of the CPMAS design characteristics were evaluated using the digital transmission system model summarized here, however, it is essential

Station Type	Quantity of Stations in Nodal Area Model
Nodal Station	1
Terminal Stations	7
Repeater Stations	5
Branching Repeater Stations	3
Total	16

3057-77E

TABLE 2-1. NODAL AREA MODEL STATION QUANTITIES

PARAMETER	RANGE
QUANTITY OF STATIONS IN NODAL AREA	3 TO 16
QUANTITY OF RADIOS IN NODAL AREA	3 TO 128
QUANTITY OF RADIOS AT A STATION	1 - 16
PERCENT OF GROUPS TERMINATED WITH MUX	0 - 100%
TYPE OF RADIO	DRAMA/DAU/FM/FKV

TABLE 2-2. MODEL SENSITIVITY PARAMETER SUMMARY

to evaluate certain CPMAS characteristics at extreme transmission system parameter values. Table 2-2 summarizes model sensitivity parameters and ranges which were used in the CPMAS study.

2.3 CPMAS Requirements

DCS requirements provide the means to assess various CPMAS configurations, place requirements upon the CPMAS functions, and arrive at an optimal CPMAS system.

DCS availability and performance requirements are presented and discussed in Section 4.1. Presented are the preliminary performance objectives for the DCS (per DCEC TR 3-74) and the updated performance objectives (per DCEC TR 12-76). A discussion of the digroup and data/VF channel availability requirements relates the digital transmission equipment to the DCS availability requirements.

In Section 4.2, the effects of employing various degrees of CPMAS upon the digroup and data/VF channel availability was analyzed. It was found that the availability of a digroup exceeds the DCS requirements for all CPMAS configurations.

However, even when performance assessment and automated fault detection/isolation are employed, the data VF cahnnel availability does not meet the DCS requirements. When a method of increasing the radio MTBF (of which trend analysis is one means) is added, the availability then meets or exceeds the DCS requirements. The above analysis assumes transmission equipment that meets DRAMA specifications. The effect of monitoring less than the DRAMA specified alarms is discussed and its effect upon data/VF channel availability presented.

Tables 2-3 and 2-4 present the results of the availability analysis from which the above conclusions were based. As shown in the tables, the unavailability is presented as a percentage of the DCS requirement. Thus, while availabilities greater than 100% do not meet the requirements of the DCS. Naturally, the smaller the unavailability, the better the performance of the CPMAS configuration.

TABLE 2-3. CPMAS PERFORMANCE (DIGROUP UNAVAILABILITY)

MANUAL FAULT ISOLATION	AUTOMATED FAULT ISOLATION	24 HR. REDUNDANT EQUIPMENT CHECK	2ND LEVEL MUX ASSESS.[1]	UNMANNED RADIO ASSESS.[1]	MANNED RADIO ASSESS.[1]	TREND ANALYSIS[2]	DIGROUP UNAVAILABILITY (% OF SPEC.)
X							91%
X		X					80%
	X						85%
	X	X					73%
	X		100%				84%
	X		50%				84%
	X			100%			73%
	X			50%			79%
	X				100%		83%
	X				50%		84%
	X		100%	100%	100%		71%
	X		50%	50%	50%		78%
	X			50%		20%	57%
	X				50%	20%	60%
	X		50%	50%		20%	56%

NOTE 1: PERCENTAGE OF UNALARMED FAILURES DETECTED
NOTE 2: PERCENTAGE OF RADIO FAILURES PREDICTED BY TREND ANALYSIS

TABLE 2-4. CPMAS PERFORMANCE (CHANNEL UNAVAILABILITY)

MANUAL FAULT ISOLATION	AUTOMATED FAULT ISOLATION	24 HR. REDUNDANT EQUIPMENT CHECK	2ND LEVEL MUX ASSESS.[1]	UNMANNED RADIO ASSESS.[1]	MANNED RADIO ASSESS.[1]	TREND ANALYSIS[2]	CHANNEL UNAVAILABILITY (% OF SPEC.)
X							118%
X		X					110%
	X						112%
	X	X					102%
	X		100%				111%
	X		50%				111%
	X			100%			103%
	X			50%			107%
	X				100%		110%
	X				50%		111%
	X		100%	100%	100%		101%
	X		50%	50%	50%		106%
	X			50%		20%	89%
	X				50%	20%	93%
	X		50%	50%		20%	88%

NOTE 1: PERCENTAGE OF UNALARMED FAILURES DETECTED

NOTE 2: PERCENTAGE OF RADIO FAILURES PREDICTED BY TREND ANALYSIS

From Table 2-3 it is shown that for all CPMAS configurations, the digroup availability exceeds the DCS requirements. In addition, the CPMAS configurations investigated resulted in up to a 35% (91%-56%) of specification reduction in the digroup unavailability.

Table 2-4 shows the data/VF channel unavailability as shown in this table using automated fault detection/isolation and performance assessment will not result in the channel unavailability meeting the DCS requirements. Including a trend analysis technique capable of predicting 20% of radio failures would then result in exceeding the DCS requirements. Thus, it can be concluded that trend analysis is one method of meeting the DCS requirements. Other methods would be improved maintenance procedures or improved equipment reliability. The assumptions and methodology used to calculate the digroup and data/VF channel unavailabilities are discussed in detail in Appendix B.

The availability analysis was used to arrive at recommendations for the CPMAS functions. Recommendations for performance assessment, fault detection/isolation, trend analysis, and corrective actions were made. These recommendations will enable the DCS to meet or exceed the updated performance and availability requirements. Some of these recommendations can be incorpordated directly into the ATEC specification, while others contain an element of risk and should be tested during the option phase of this contract.

2.4 CPMAS Alternatives

During the conduct of the CPMAS Study contract, a series of alternatives were defined and evaluated with recommended implementation approaches selected. This section summarizes the four major functions that were analyzed, namely:

(1) Performance Assessment

(2) Trend Analysis

(3) Fault Detection and Isolation and

(4) Telemetry

2.4.1 Performance Assessment Alternatives

An equipment failure analysis was performed in order to assess the usefulness of measuring a particular parameter and to evaluate performance assessment and trend analysis techniques. This analysis consisted of two

investigations: a fault cause/effect investigation and a failure rate investigation. The fault cause/effect investigation purpose was to determine which faults occur in the multiplexer, radio, and the propagation media; what symptoms these faults would have; and what performance related parameters would be affected. The purpose of the failure rate investigation was to provide a quantitative estimate of the failure rates of the various modules of the DRAMA radio. These failure rates can then be used to assess the benefits of measuring digital transmission system parameters.

Techniques for performance assessment are discussed, as is the method by which a recommended performance assessment approach was selected. Table 2-5 summarizes the selection process of the digital radio performance assessment technique. Each technique was rated from zero to ten (with ten the best) for its ability to satisfy each of the selection criteria. These ratings were used to evaluate a figure of merit for each technique. It was found that channel estimation is the best single performance assessment technique. Also, channel estimation plus DRAMA BITE is the best combined approach and is more cost effective than channel estimation alone. For partial response systems, it is recommended that format violation be used in addition to channel estimation and DRAMA BITE.

Format violations and DRAMA BITE contain virtually no risk and, thus, no further testing of these techniques is required. The channel estimation technique contains sufficient risk to make it desirable to perform on-site testing during the option phase of the contract.

2.4.2 Trend Analysis Alternatives

The results of an analysis showing the effect of trend analysis upon equipment availability is discussed. It is shown that failure prediction can greatly increase the equipment mean time between failures. Parameters to be used for trending and the parameter selection process are discussed. Table 2-6 summarizes the results of the trend analysis parameter selection process. The parameters recommended for trending are transmitted signal power, signal-to-distortion ratio, and signal-to-noise ratio.

TABLE 2-5. DIGITAL RADIO PERFORMANCE ASSESSMENT TECHNIQUE SELECTION

CRITERIA (WEIGHTS) / TECHNIQUE	SPECIFICATIONS MEASURED (1)	TREND ANALYSIS PARAMETERS (2)	BER ESTIMATION ACCURACY (2)	SPEED OF ASSESSMENT (1)	COST (1)	FIGURE OF MERIT
ERROR COUNTER* (FORMAT VIOLATIONS)	0/10 *	0	0/10 *	0/2 *	0/9 *	0/41 *
PSEUDO ERROR COUNTER	10	0	6	5	6	33
EYE OPENING	5	0	4	10	6	29
CHANNEL ESTIMATION	10	6	8	10	5	53
JITTER MONITOR	5	0	0	10	6	21
DRAMA BITE	5	6	2	10	9	40

* FORMAT VIOLATIONS WOULD ONLY BE USED WITH PARTIAL RESPONSE (DUAL RATINGS INDICATE WITHOUT AND WITH PARTIAL RESPONSE)

TABLE 2-6. TREND ANALYSIS PARAMETER SELECTION

PARAMETER / CRITERIA (WEIGHTS)	PARAMETER AVAILABILITY (2)	PRECURSOR TO EQUIPMENT FAILURE (2)	TRENDABILITY			RELATIVE NUMBER OF DEGRADATIONS (2)	TOTAL
			INSENSITIVITY TO EXTERNAL PARAMETERS (1)	PARAMETER MEASUREMENT ACCURACY (1)	MODELABILITY (1)		
TRANSMITTED SIGNAL POWER	10	10	10	10	10	3	76
SIGNAL-TO-NOISE RATIO	10	5	7	8	4	5	59
JITTER	3	10	9	5	6	4	54
SIGNAL-TO-DISTORTION RATIO	10	10	9	9	8	7	80
RECEIVED SIGNAL LEVEL	10	4	2	8	4	2	46
TRANSMITTER FREQUENCY DRIFT	6	10	10	7	8	1	59
BIT ERROR RATE	10	2	2	5	2	10	53

Five techniques for trending are presented and discussed. These techniques are existing approaches that are applicable to trending parameters of a digital transmission system. The process used to recommend a trend analysis technique is presented and discussed. Table 2-7 summarizes the results of the trend analysis technique selection process. Exponential smoothing and direct smoothing were the best CPMAS trend analysis techniques with each receiving about the same figure of merit. Exponential smoothing is the recommended trend analysis technique.

The trend analysis CPMAS function has sufficient risk to warrant on-site testing. This testing will attempt to verify the prediction capability of the recommended parameters as well as the trending capability of exponential smoothing. This testing should be performed during the option phase of this contract.

2.4.3 Fault Detection/Isolation

In the DCS the automation of the fault detection/isolation process will furnish the technical controller with rapid and accurate resolution of faults and provide the controller with the information necessary to effect repair and restoral of service more efficiently.

The presence of equipment failures or faults in the DCS is evidenced by the generation of binary alarms and the crossing of critical thresholds by analog and counted parameters. At times, alarms of a sympathetic nature will occur in non-faulted equipments as a result of their connection to faulted equipment. The fault detection and isolation algorithms process this alarm data to yield the description and location of the faulted equipment as well as the location of the fault.

The fault analysis technique utilized to provide the desired information and meet the speed and accuracy requirements must be amenable to the characteristics of the DCS. Some of the specific features that must be addressed include:

1. The large number of equipments/sites in the DCS and the associated alarm and monitor parameter database;
2. The diverse nature of the nodal areas, stations, and equipments that compose the DCS;

TABLE 2-7. TREND ANALYSIS TECHNIQUE SELECTION

TECHNIQUE / CRITERIA (WEIGHTS)	FORECAST ACCURACY (2)	LOW STORAGE REQUIREMENTS (2)	LOW PROCESSING COMPLEXITY (2)	MODEL UTILIZATION (1)	REACTION SPEED (1)	TOTAL
REGRESSION	5	1	2	10	8	34
MOVING AVERAGES	10	2	10	6	8	58
EXPONENTIAL SMOOTHING	10	9	10	6	10	74
DIRECT SMOOTHING	10	10	8	7	10	73
BOX-JENKINS	10	1	2	9	8	43

3. The possible occurrence of multiple independent faults within an area of nodal responsibility;
4. The sympathetic alarming of non-faulted equipments at many sites which could be remotely located from the faulted site;
5. The constantly evolving characterization of the DCS and the equipments that compose it.

Finally, the techniques employed in optimizing the fault detection/ isolation process to these needs and atributes must be practical in terms of hardware and software complexity and size.

There are two general techniques for processing the input data to arrive at the desired conclusion, sequential and parallel processing. Sequential processing involves making decisions on each item of data and utilizing the results of many decisions to arrive at a conclusion. An example of sequential processing is a tree approach where the logical decisions made define a path through the tree to the desired conclusion. The second approach, parallel processing, involves transforming and combining many data items into a single observation which is directly associated with the desired conclusion. An example of parallel processing is a signature approach where several binary alarms are combined in a binary signature which in turn defines a conclusion.

Examination of the attributes of each technique in light of the requirements and constraints of the DCS lead to recommendation of a hybrid sequential/signature approach to fault analysis. In this approach faults are detected and isolated down to an equipment level in a sequential manner and signatures are utilized for the equipment alarms to further fault isolate the equipments. The sequence of actions required is shown in Figure 2-3.

In order to deal with multiple faults within a nodal area, algorithms to assess the severity of alarms related to individual stations and to utilize that assessment, in conjunction with station location, to prioritize and queue the work for the fault isolation algorithm have been recommended.

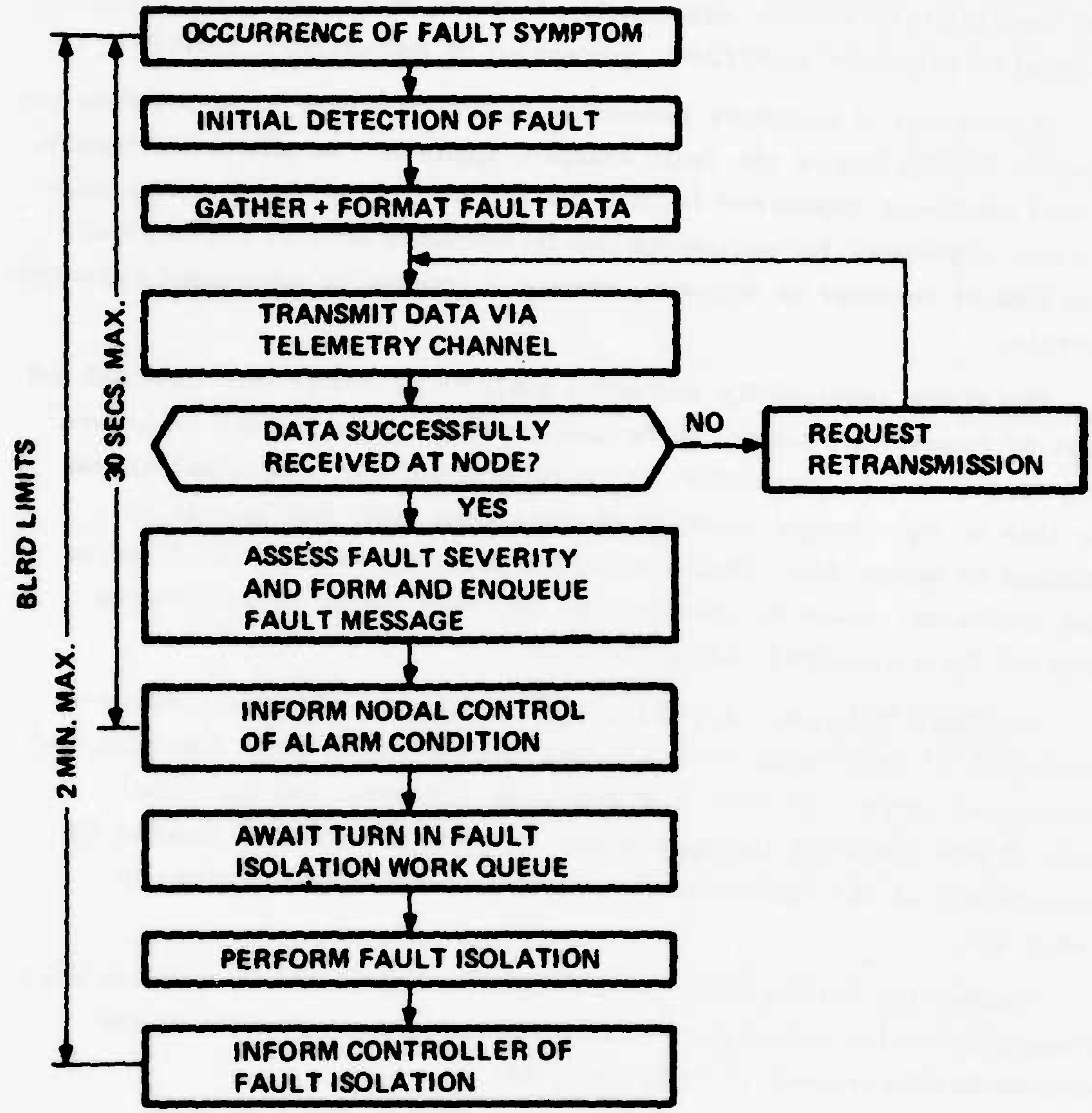

FIGURE 2-3. FAULT DETECTION/ISOLATION SEQUENCE

The problem of sympathetic alarms in the fault isolation process is dealt with by utilization of correlation jumps contingent on the identified signature definition to direct fault analysis to the faulted equipment. Upon resolution of faults, suppression of alarms of a sympathetic nature is employed to eliminate superfluous processing of non-existent faults.

Utilization of signature processing at the equipment level provides for inherent flexibility of the fault analysis approach. An additional benefit of utilization of signatures is that omissions of errors in the definition of fault signatures for equipments can be corrected easily, without modifications of hardware or software, through a process of supervised signature learning.

The alarms required for signature analysis of faults were examined and a set of recommended alarms, to be used in fault detection and isolation, were specified. In particular, it is recommended that individual alarms for loss of input/output digroups on the second level mutliplexer be provided to assure fault isolation to the desired equipment and likewise that individual alarms be provided for the input/output digital channel ports of the first level multiplexer.

Ancillary functions of fault analysis including operator interfaces, resolution of inter-nodal faults, manual initiation of fault isolation and learning of unresolved fault signatures are discussed and functional descriptions given for the approaches. A functional diagram showing the relationship of the various fault analysis sub-functions is given in Figure 2-4.

The section dealing with fault analysis is concluded by examples which illustrate how the techniques recommended work and a summation of the recommendations related to fault analysis.

2.4.4 Telemetry

The telemetry network is an integral part of the nodal area CPMAS shown in Figure 2-5. The Wideband Digital CPMAS data at each of the stations of the nodal area is monitored by the station's Wideband Digital Monitoring Set (WDMS) and transmitted via the Communications Interface Set (CIS) and a telemetry channel to the Nodal Control Processing Subsystem

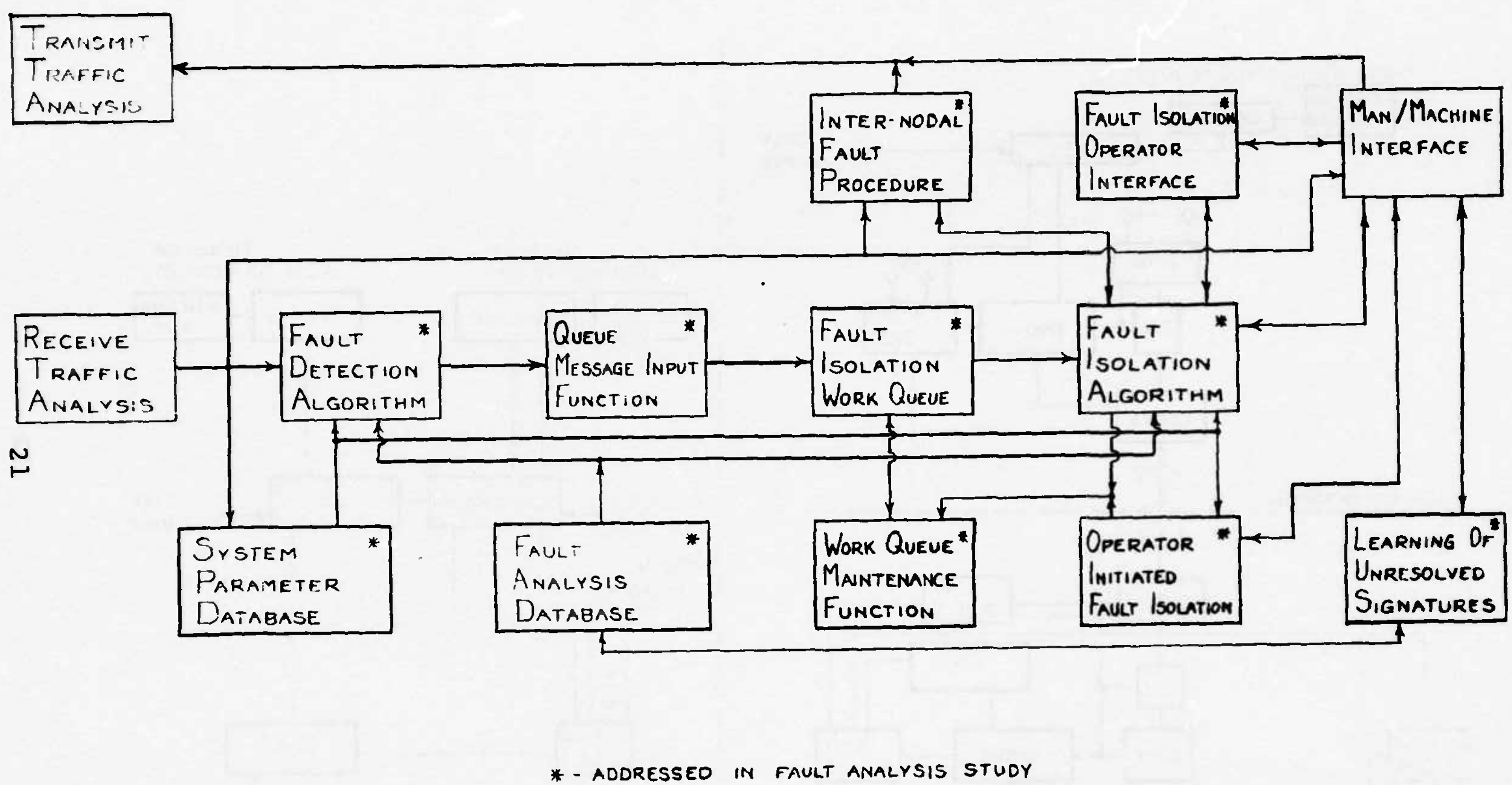

FIGURE 2-4. INTER-RELATION OF FUNCTIONS IN FAULT ANALYSIS

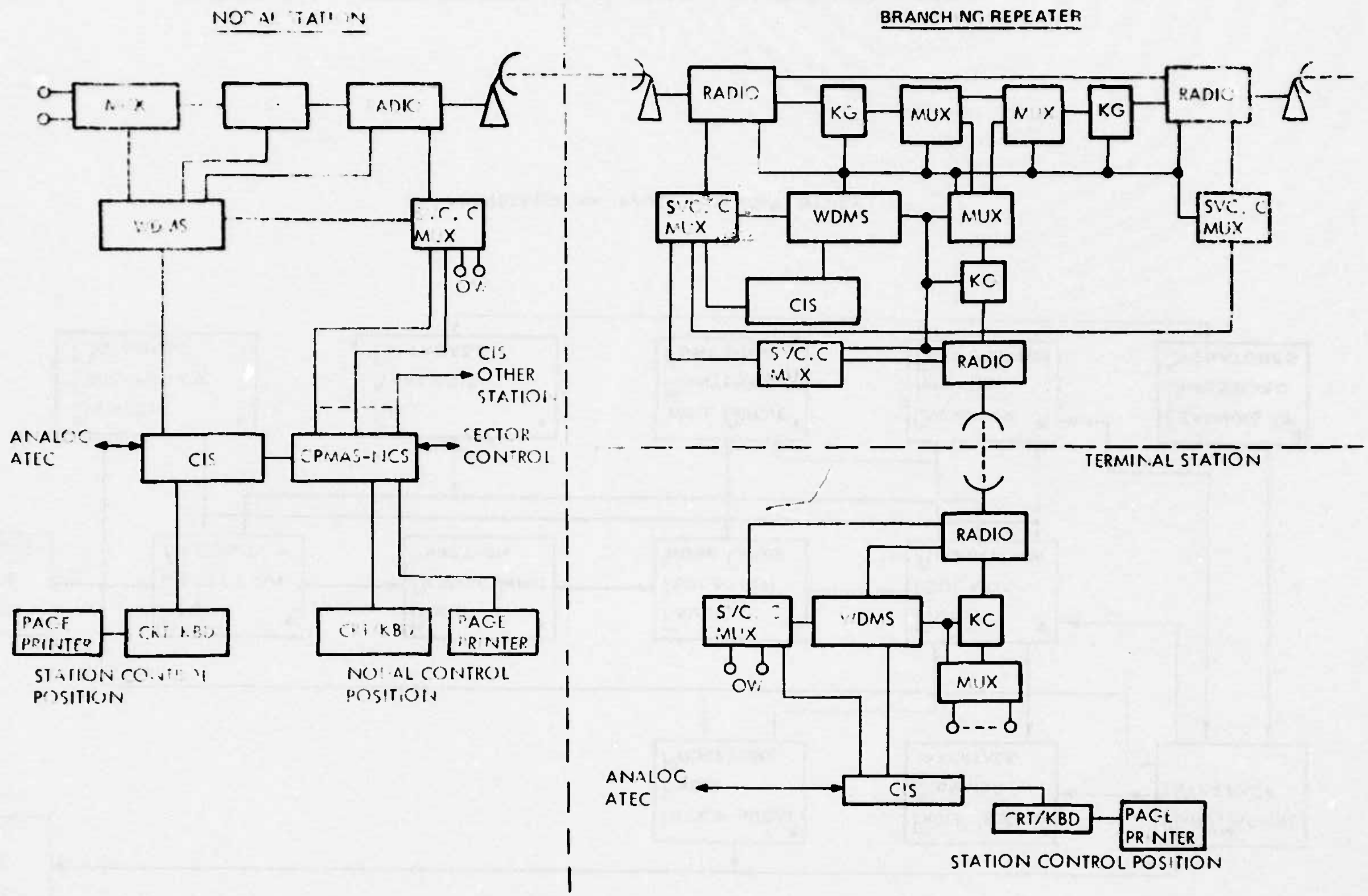

FIGURE 2-5. CPMAS SYSTEM BLOCK DIAGRAM

(CPMAS-NCS). The Service Channel Multiplexer provides telemetry channel access as well as orderwire channels for Technical Control. The relationship of the telemetry channel within the nodal area CPMAS is simply shown in Figure 2-6. All communications between a station and nodal control are transmitted via its assigned telemetry channel.

Each telemetry channel must provide digital telemetry communications among the three major areas shown in Figure 2-7, the Measurement Acquisition Subsystem (MAS) elements including WDMS, Station Controller Position and Nodal Control.

The basic Wideband Digital CPMAS telemetry functions are:

1. Transmit alarm, status and performance assessment data from the Wideband Digital Monitoring Set (WDMS) to Nodal Control via the CIS and Telemetry Channel.
2. Transmit alarm, status, control, reporting and display messages between nodal control and station control via the CIS and telemetry channel.
3. Transmit nodal control commands to Wideband Digital Monitoring Set (WDMS)
4. Provide interstation control communications via Nodal Control.

The Wideband Digital CPMAS data at WDMS is communicated to Nodal Control (CPMAS-NCS) via the telemetry channel. The transmission time for this data must be sufficiently small so that when added to processing delays, the ATEC System Description requirement to display a fault to the nodal controller within 30 seconds can be met. The time to transmit the fault data is determined by the length of the message which is a function of coding, i.e., ASCII or Binary and the telemetry channel bit rate.

Binary coding is the form recommended for CPMAS data to be accessed at the WDMS. ASCII coding requires a binary to ASCII conversion process at WDMS and the reverse conversion back to binary at the nodal control processor. Binary coding is more compact that ASCII and thus provides more efficient and speedier transmission of data to nodal control. The rationale supporting the recommendation for using binary is presented in Section 5.4.

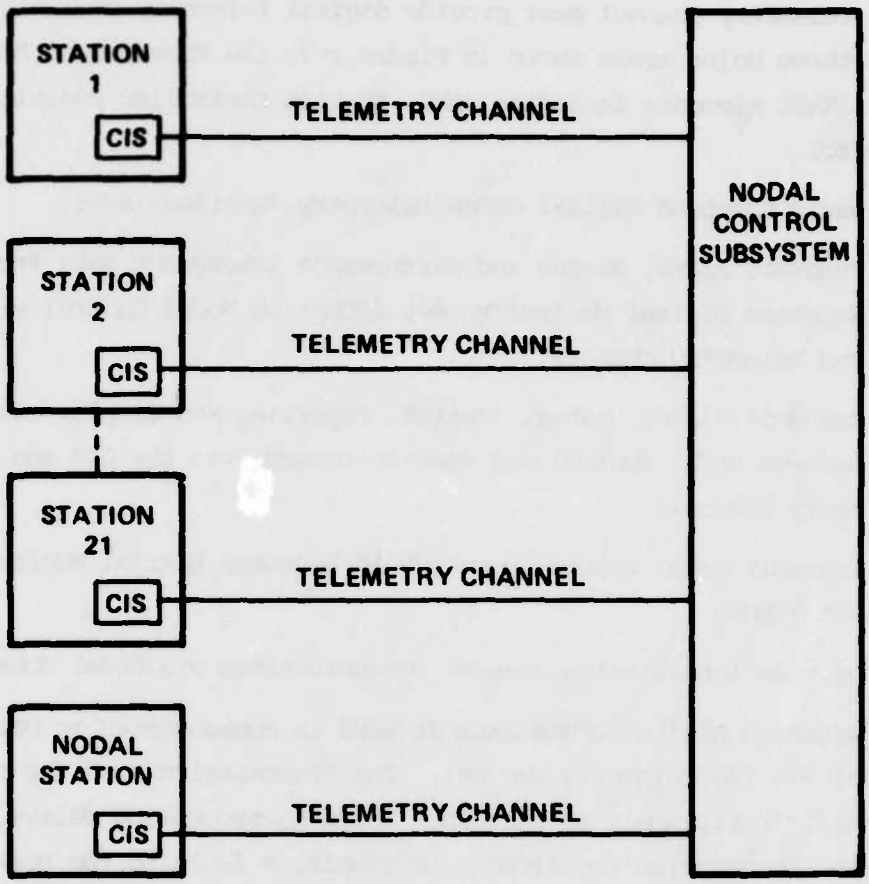

FIGURE 2-6. MODEL TELEMETRY NETWORK

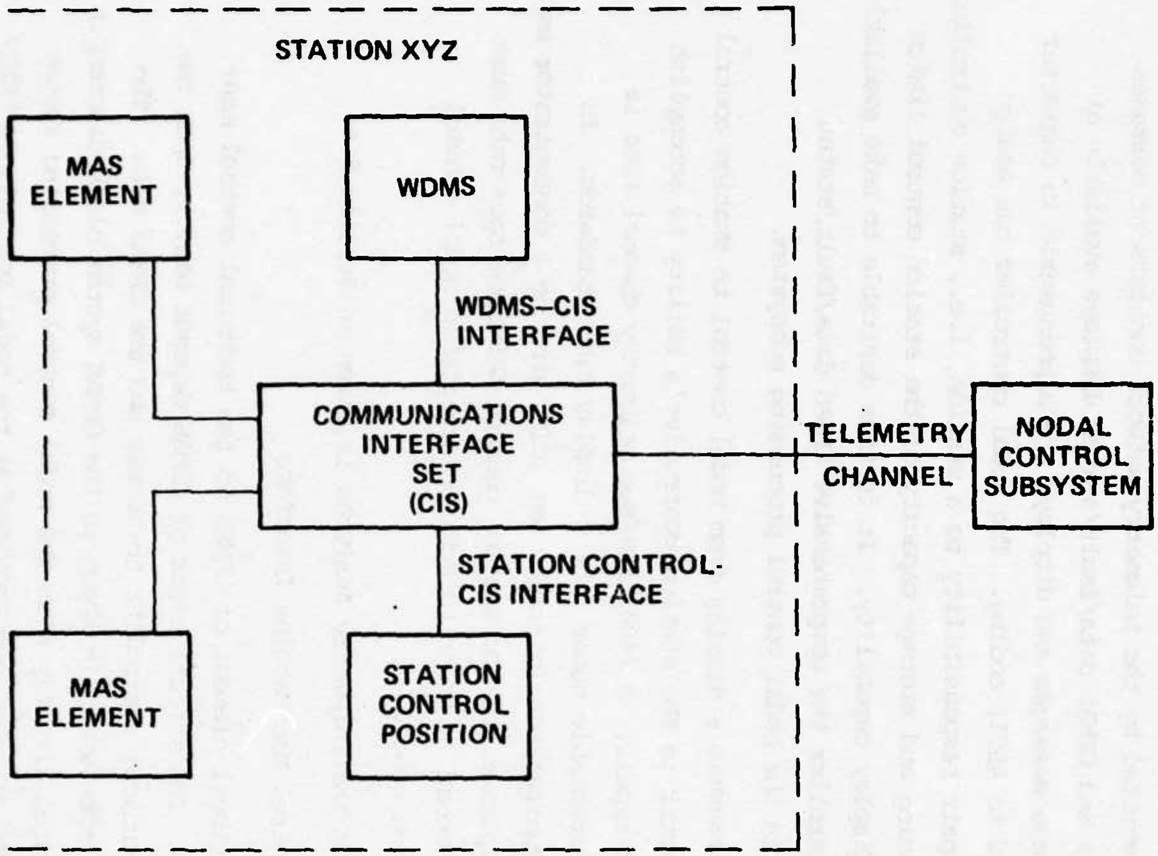

FIGURE 2-7. TELEMETRY COMMUNICATIONS

The same message coding should be used to report alarms and status to station control in Standalone operation.

The station control position communicates with nodal control and with other station control positions via nodal control. This communication which must be transmitted by the telemetry network consists of messages between controllers and CPMAS data/fault/status displays available at nodal control. These messages and displays are alphanumeric in character and are most suited to ASCII coding. The nodal controller can assign fault isolation/repair responsibility to a station, i.e., station controller. The limited processing and storage capacity of the station control limits its fault/status display capability. It is thus desirable to make available to the station controller the comprehensive CPMAS data/fault/status displays residing in the nodal control processing subsystem.

The time to transmit a display from nodal control to station control is an important factor in the station controller's ability to accomplish rapid restoral and repair. A 2400 bits/sec telemetry channel rate is required to meet acceptable human factor display time standards. In addition, the Communications Interface Set (CIS) must be a concentrator as opposed to a multiplexer and the station control-CIS interface rate must be 2400 bits per second in order to achieve acceptable nodal control display transmission times.

Description of the Telemetry Analyses is given in Section 5.4.

2.5 Technical Control Man-Machine Interface

A major functional element of CPMAS is the technical control man-machine interface. The effectiveness of CPMAS depends heavily upon the ability of the technical controller to access and use CPMAS data. The nodal control position which is shown in the CPMAS system block diagram in Figure 2-5 interfaces directly with the nodal control processing system (CPMAS-NCS). CPMAS displays are provided at the nodal controllers' CRT/ Keyboard unit and hard copy is provided by the page printer. CPMAS data from all stations within the nodal area (up to 16 stations per the ATEC System Description) is transmitted to the CPMAS-NCS processing system

where fault detection/isolation and transmission network performance assessment is accomplished. The results of these CPMAS processes are displayed for the nodal controller so that he can exercise judgment and make task assignments to maintenance and station control personnel.

The technical control displays and display organization developed during the CPMAS study phase were directed toward fault detection/isolation and fault status reporting. CPMAS fault information displays are ordered in the hierarchy, shown in Figure 2-8, which leads from a general overview of the nodal area status to levels of increasing detail.

The Fault Summary display, the highest display in the hierarchy, provides an overview of the nodal area fault status. All faults in the nodal area which have not been cleared by the nodal controller are displayed in the fault summary display. The second level of the display hierarchy, the fault detail display, provides fault data for a specific fault listed in the fault summary display. A control entry on the fault summary display selects a fault detail display. The third and lowest level of the hierarchy provides alarm and status data for specific elements listed in the fault detail display. The third level display provides status for a specific equipment, transmission path, trunk or circuit and is selected by a control entry on the Fault Detail display.

Detail descriptions of the Nodal Control Displays are given in Section 6.

2.6 Recommended CPMAS Approach

GTE Sylvania's recommended CPMAS approach is an integrated system which provides automated communications performance monitoring and assessment for DCS digital transmission systems. The design of the system and the subsystem elements is based primarily upon the ATEC System Description; the Baseline Requirements Document (BLRD); the GTE Sylvania developed DCS digital transmission system model; GTE Sylvania's recommended techniques for performance assessment, trending, fault analysis, and telemetry; the various working meetings and reviews held with RADC/DCLD, AFCS/DOYTN, USA CEEIA, ESD, MITRE, DCA/DCEC, and GTE Sylvania personnel; and the Statement of Work (SOW) for this study.

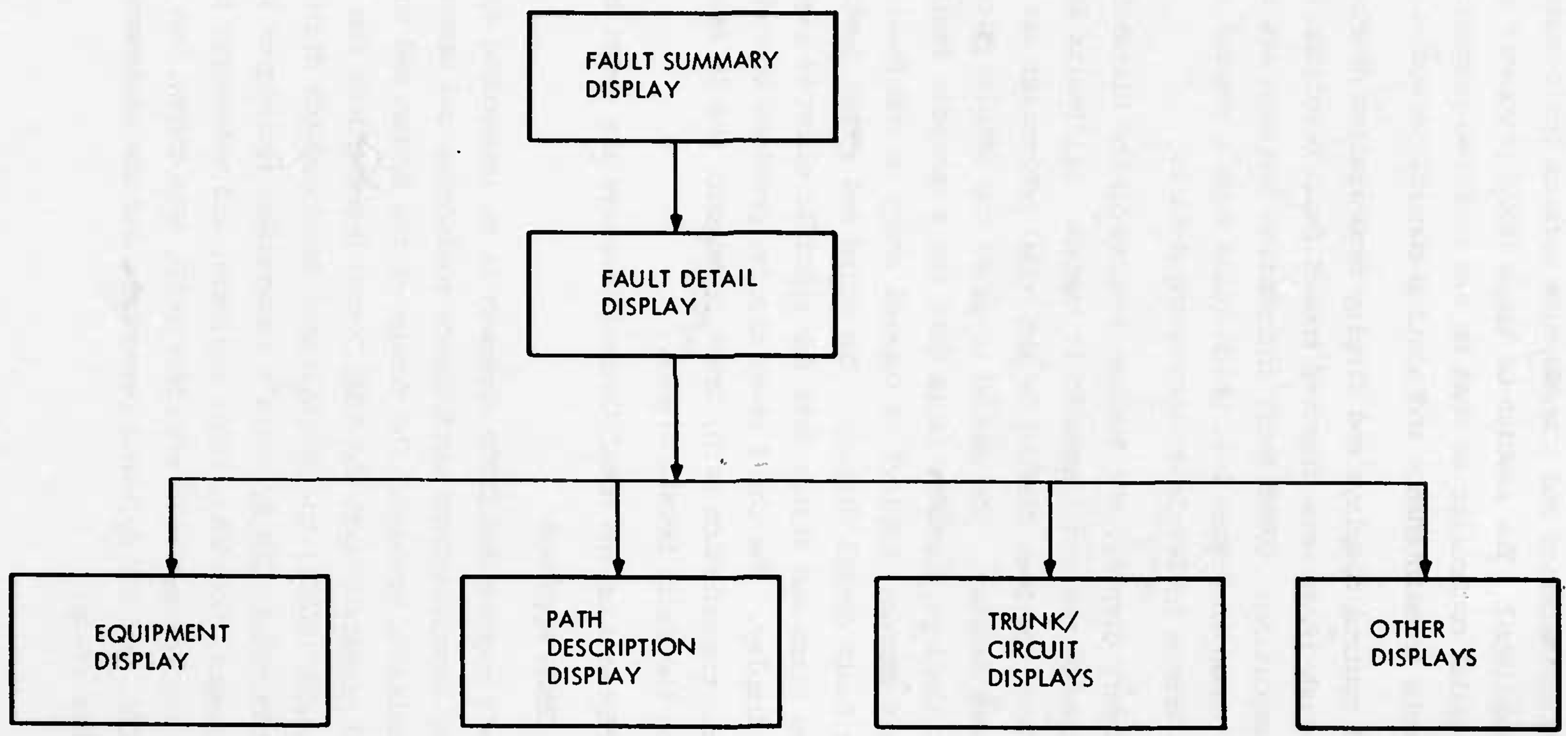

FIGURE 2-8. FAULT DISPLAY HIERARCHY

The SOW idnetifies seven primary CPMAS functions. These are performance monitoring, performance assessment, fault detection and isolation, trend analysis, corrective actions, reporting and telemetry. Sections 4, 5, and 6 of this report define these functions in terms of CPMAS, and discuss alternative approaches and recommendations for their functional implementation.

The ATEC System Description and the Baseline Requirements Document define a baseline system approach for the seven primary functions for automated tech control of the DCS transmission system, including both analog and digital transmission elements. These documents have been used as a guideline in developing the CPMAS system for the DCS digital transmission system.

Four general functions are required for CPMAS. These four functions are listed in Table 2-8. Also listed are the five functional units (ARF, PCF, WDMF, NCS and CTF) required to implement these functions according to the ATEC System Description, and the four functional units (CPMAS-D, CPMAS-NCS, CIF and Station Control Position) developed in the CPMAS System Study for wideband digital transmission system CPMAS.

The CPMAS-NCS, CIF, and Station Control Positions are essentially identical to the NCS, CIF and CTF functional units as described in the ATEC System Description. The primary difference is that the CPMAS-NCS combines the functions of the NCS and the nodal control CTF.

The CPMAS-D functional unit effectively combines the ARF, PCF and WDMF functions as described in the ATEC System Description. This includes binary alarm scanning and change-of-threshold detection, frame error rate calculation and threshold crossing detection, analog parameter scanning, conversion, and threshold crossing detection, performance assessment, command reception and execution, and fault reporting by exception.

The recommended hardware implementation of the CPMAS-D unit consists of a single control microprocessor and a variable amount of data acquisition hardware, depending upon the station configuration. The data acquisition hardware consists of binary monitor point signal conversion and multiplexing logic, frame error monitor point signal conversion and error rate

TABLE 2-8. FUNCTIONAL UNITS FOR DIGITAL TRANSMISSION

GENERAL FUNCTION	ATEC UNIT	CPMAS UNIT
Monitoring And Performance Assessment At Digital Transmission Equipment	ARF PCF WDMF	CPMAS-D
NODAL Control Processing and Man-Machine Interface, for Control of The NODAL Area of Responbility	NCS CTF	CPMS-NCS
Communication Interface Between CPMAS/ATEC Units and NODAL Control Subsystem (CPMAS-NCS)	CIF	CIF
Local Station CPMAS Man-Machine Interface for Station Controller	CIF	Station Control Position

calculation logic, analog parameter signal conversion and multiplexing logic, and performance assessment parameter conversion.

It has been calculated that a single 8-bit MOS microprocessor with 8K Bytes of data memory and 8K Bytes of program memory can control the CPMAS-D function for an 8-radio DRAMA nodal station. This size station contains 272 pieces of transmission equipment which present a combined total of 4512 binary monitor points, 312 frame error pulse monitor points, 448 analog monitor points and 16 performance assessment monitor points. For this many points, the CPMAS-D combined scan rate is about 50 msec/scan, and the CPMAS-D implementation requires approximately 200 circuit cards and 400 watts of prime power.

Figure 2-9 presents the CPMAS hardware element family tree.

The recommended CPMAS software system is hierarchical by nature. The system is made up of four functional units:

a) CPMAS-NCS software which performs the nodal control CPMAS functions and processing for nodal controller displays and controls.

b) CPMAS-D software (implemented with firmware) controls the monitoring of performance and assessment parameters of the digital transmission equipment at a station.

c) Station Controller Position software primarily provides the means by which the station controller can monitor and control the equipment at the station.

d) Communications Interface Set (CIS) software coordinates communication interface among CPMAS/ATEC units at the station, the Station Controller Position and Nodal Control Subsystem.

The CPMAS-NCS is central to the CPMAS function. The Nodal Control Processing System software coordinates reception and request of status and performance assessment data from the CPMAS-D units of all stations within the Nodal Area. In addition, the NCS software controls the fault detection/isolation and performance assessment function for the nodal area. The software resident at the NCS also formats the display used in status and

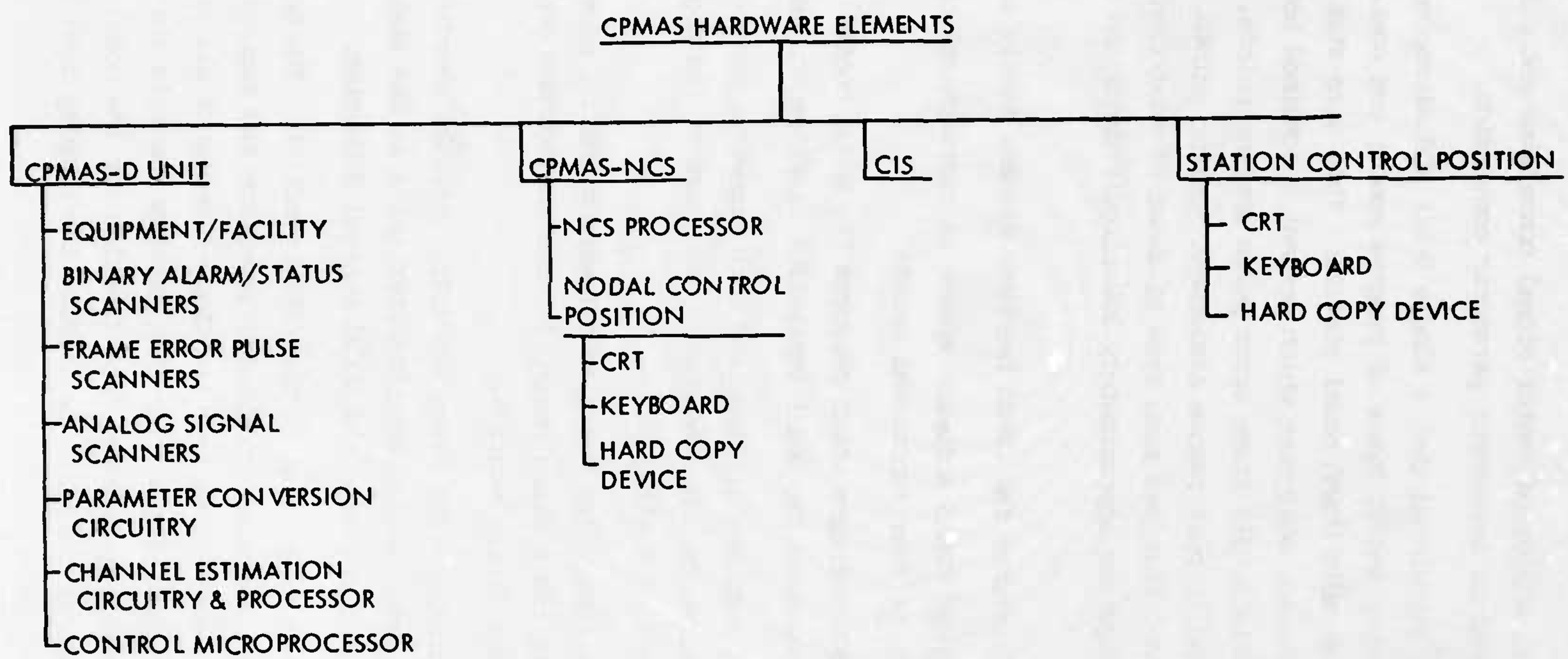

FIGURE 2-9. CPMAS HARDWARE ELEMENT FAMILY TREE

alarm notification. Similarly, reports for system dissemination are formatted and generated both automatically and with operator intervention at the NCS. The software also maintains CPMAS parameter histories and data bases for the nodal area. The NCS software also coordinates CPMAS data transfer and message communication between the station controls within the nodal area and the sector control.

The data gathering function of the CPMAS system is provided by the CPMAS-D subsystem. The software resident in the CPMAS-D coordinates and controls the data monitor function. It performs exception processing to determine state changes, and it coordinates status data transmission to the respective nodal control position and station control position. In addition, the CPMAS-D software performs effectivity processing for requests from the NCS and the respective station control positions.

The data transfer between the detection and measurement elements of the CPMAS system, the station control position, and the nodal control position is coordinated by the CIS subsystem. The software resident in the CIS controls this function. In addition, the CIS software provides the protocol processing necessary for inter-site communication.

The station control function (controller terminal function) is, like the nodal control function, under software control. The software resident at the station control will control the man-machine interface for the CPMAS function at the station. This is the means by which the station controller can operate in the stand alone mode in the event of a CPMAS-NCS failure. Additionally, the software will coordinate traffic data between the station control position and the CIS. These software functions require that the station control function be performed by an intelligent terminal. Figure 2-10 presents the CPMAS operational software family tree.

2.7 CPMAS Feasibility Demonstration Plan (Option Phase)

The CPMAS study phase analyzed the DCS transmission system, the requirements placed upon this system, the evolved wideband digital CPMAS requirements and recommended a wideband digital CPMAS design approach. Certain critical issues which exist in the CPMAS design approach will be

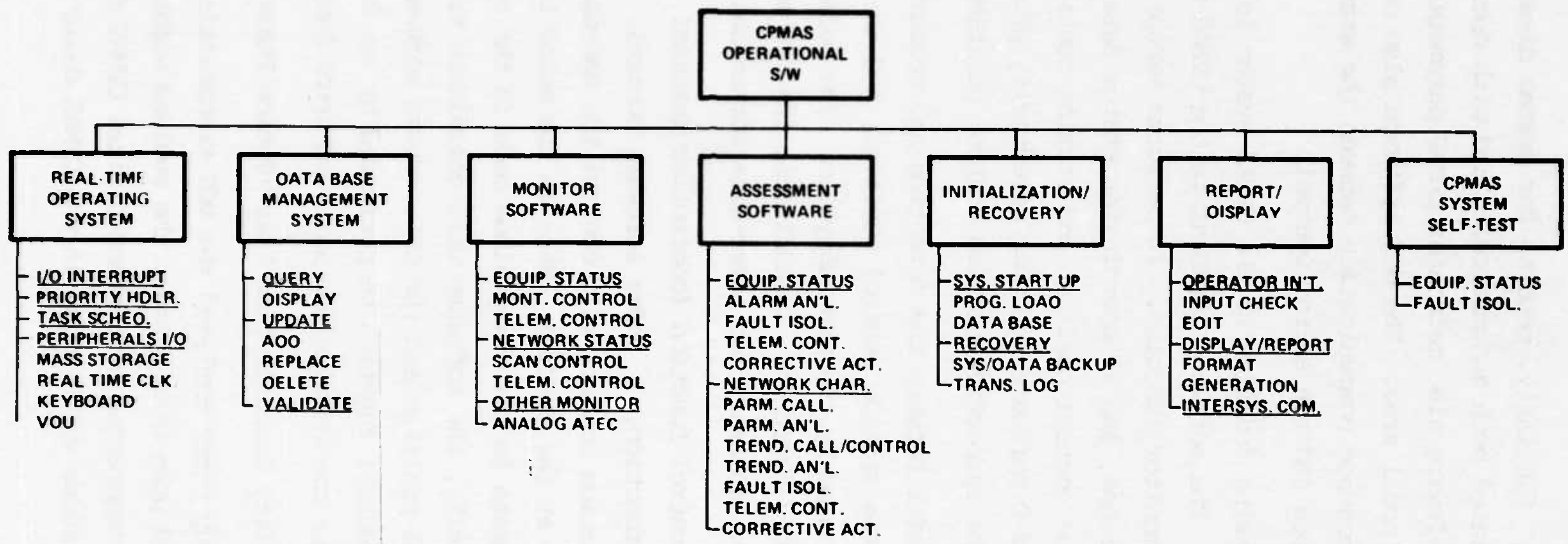

FIGURE 2-10. CPMAS OPERATIONAL SOFTWARE FAMILY TREE

addressed during the feasibility testing program to guarantee a successful uninterrupted production phase program. The critical issues include new performance assessment, fault detection/isolation, and trending techniques. Man-machine operations and higher order language utilization will also be evaluated for CPMAS applications.

The option phase program will:

(1) Develop and test WDMS feasibility models.

(2) Perform early field test evaluation of the channel estimation and eye opening monitor performance assessment techniques.

(3) Implement and program a CPMAS test processor subsystem.

(4) Perform a field test site survey.

(5) Perform field test of CPMAS feasibility models at Fort Huachuca or other CONUS test facility.

The wideband digital CPMAS option phase will evaluate the recommended wideband digital CPMAS approach using the functional evaluation model shown in Figure 2-11. Feasibility models of the Wideband Digital Monitoring Set (WDMS) will be fabricated. Nodal control and station CPMAS functions and simulation of the digital transmission system and Communications Interface Set (CIS) will be implemented in a test processor.

Figure 2-12, the in-plant evaluation model, indicates the test arrangement for in-plant testing of wideband digital CPMAS. Two CRT/Key-board terminals are used to emulate the station and nodal control display terminals. The test processor interfaces with the WDMS to receive and transmit WDMS to nodal control and WDMS to station control communications. The test processor simulates the transmission equipment's monitor and performance assessment inputs to the WDMS for in-plant evaluation and also for WDMS loading during field testing.

During the initial months of the CPMAS option phase, a field test will be conducted to evaluate the performance assessment techniques as a means of assessing digital transmission system performance. Feasibility models will be fabricated and used in the preliminary field test evaluation model shown in Figure 2-13. The feasibility models will be incorporated into the WDMS feasibility models for the CPMAS in-plant and field tests.

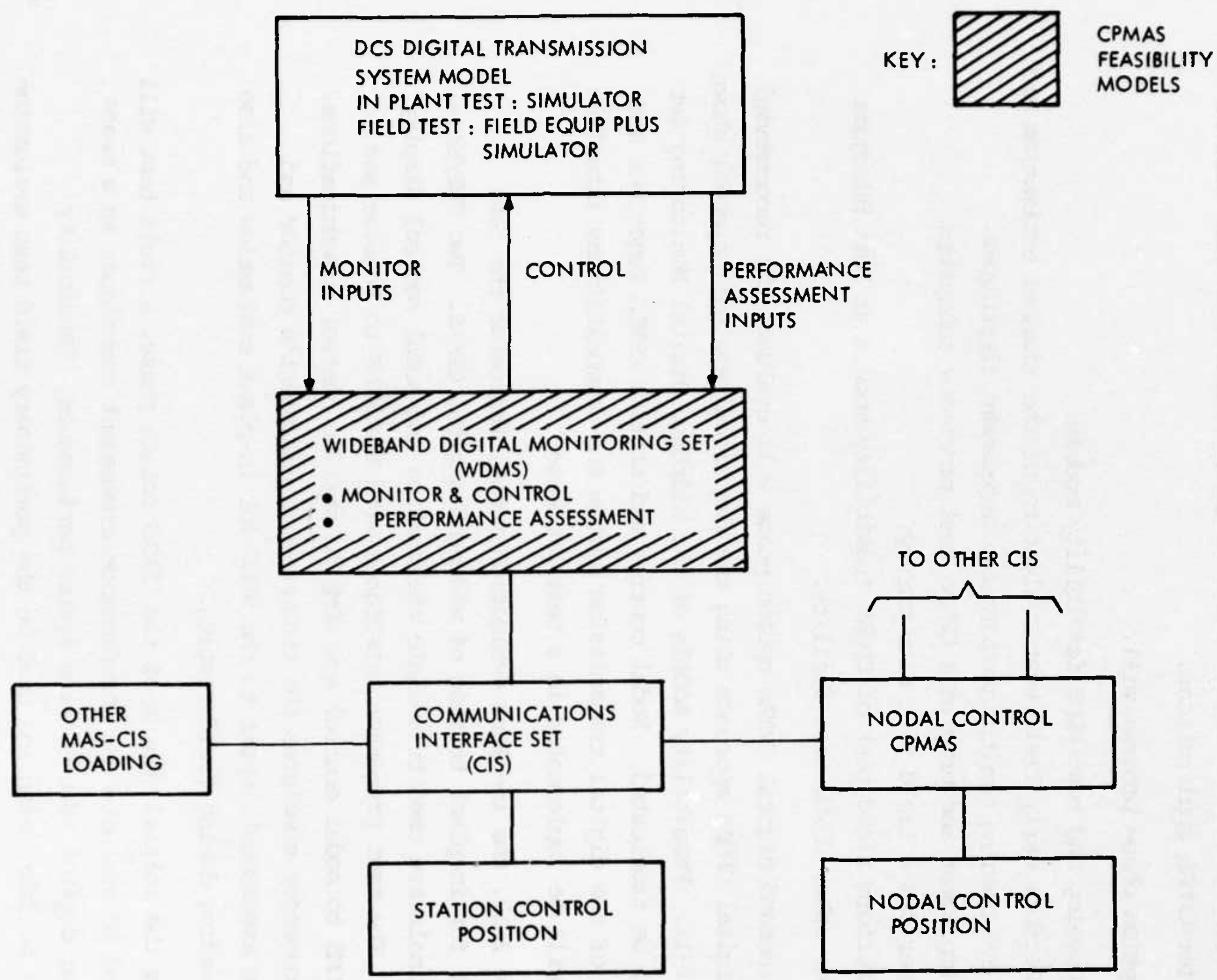

FIGURE 2-11. FUNCTIONAL CPMAS EVALUATION MODEL

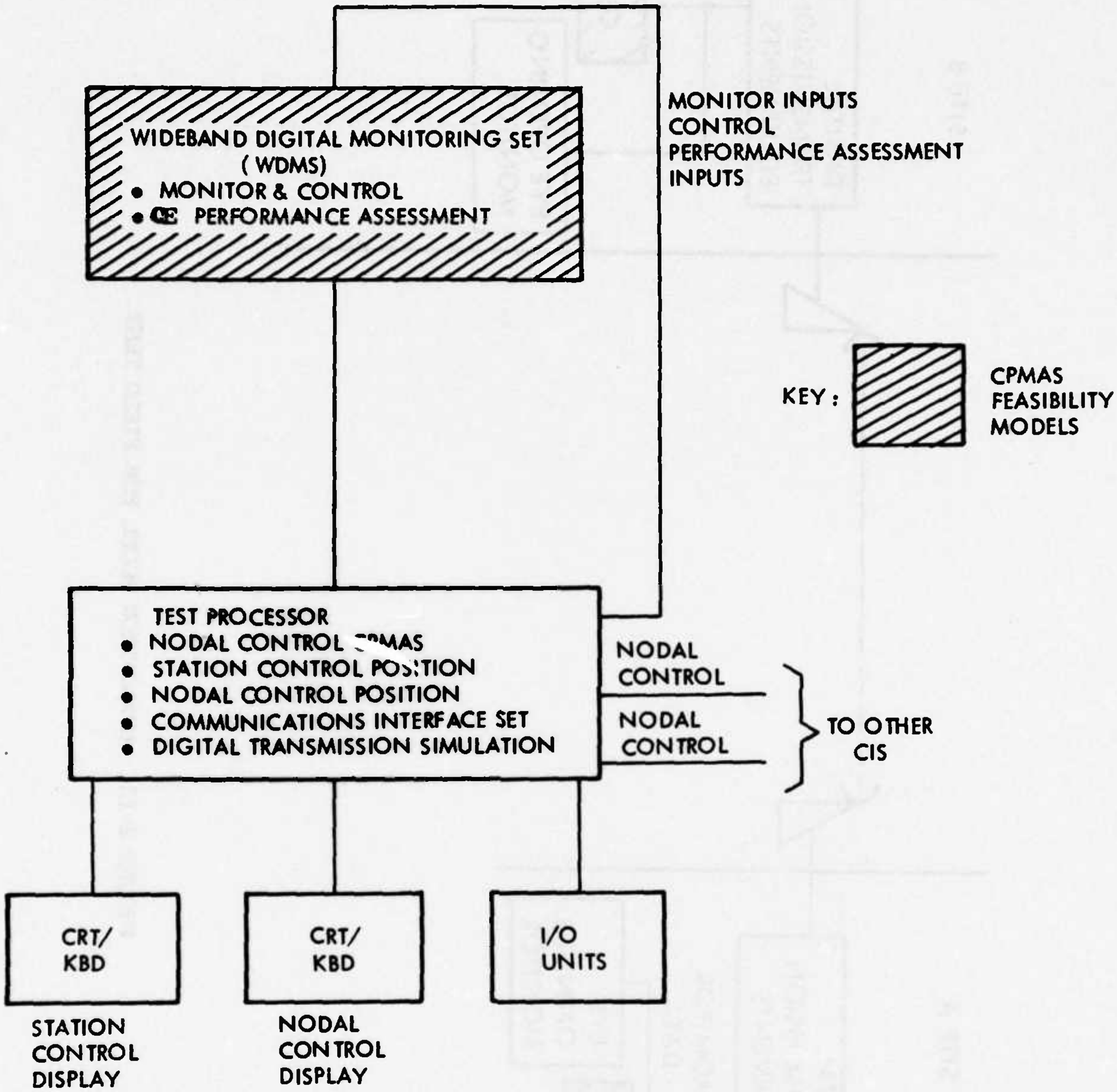

FIGURE 2-12. CPMAS EVALUATION MODEL

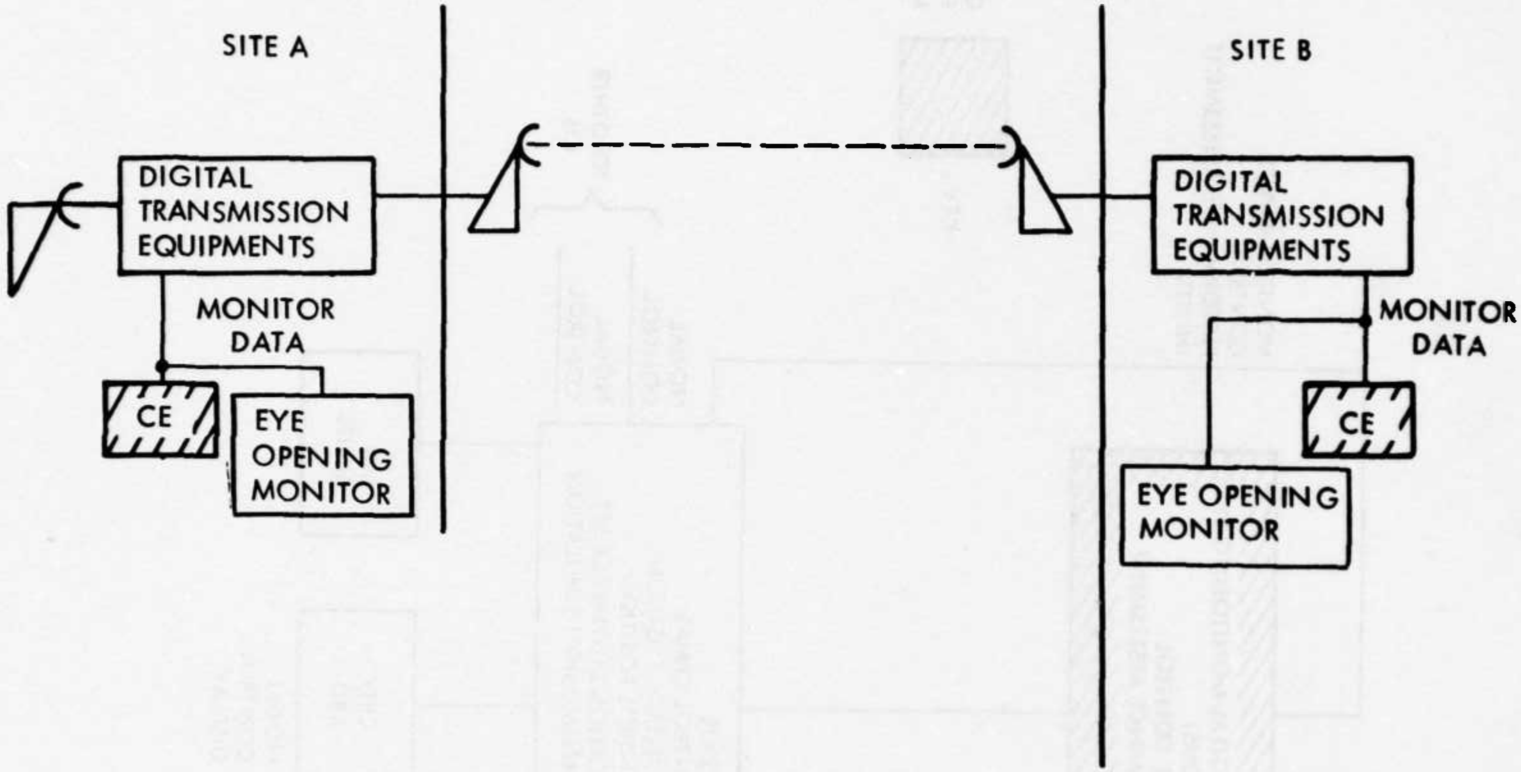

FIGURE 2-13. EVALUATION MODEL FOR FIELD TEST

2.8 Future Related Research and Development

During this study, areas that warrant further research and development were identified. These research and development areas would aid in arriving at an optimum CPMAS for the digital transmission system as well as defining additional capabilities that could be included for DCS system control. The four areas for future R&D include automated digital network control, analysis of restoration/alternate routing procedures in an automated environment, electronic counter counter measures (ECCM), and programmable multiplexer design and development.

By nature of a study GTE Sylvania is performing for DCEC, Contract No. DCA100-76-C-0064, it has been determined that a Digital Network Control capability, which was defined during the study, offers advantages to controlling the DCS that do not exist at the present time. These advantages are summarized in Table 2-9.

Because of this, it is recommended that the development and demonstration of a feasibility model of a Digital Network Control DNC element be considered for future research and development. Section 9 describes the DNC and the recommended feasibility program. Digital network control provides the technical controller with the ability to reconfigure channels at local and remote stations from a central technical control position. The DNC program scope would demonstrate the feasiblity of automatic digital channel reconfiguration, digital channel access, and remote control of digital channel reconfiguration.

Analysis of restoration/alternate routing procedures in an automated environment would be beneficial in incorporating DNC into the DCS. The scope of this effort would be to study the connectivity data base organization, data base update procedures and controls.

The ECCM R&D program would determine manifestations of ECM in a digital environment, evaluate modifications or additions to the CPMAS performance assessment technique for detecting ECM, and provide for testing the approach.

TABLE 2-9. DIGITAL NETWORK CONTROL APPLICATION SUMMARY

DIGITAL NETWORK CONTROL (DNC)

CATEGORIES OF DNC OPERATIONS	TYPES OF APPLICATION	DCS BENEFITS GAINED
TRANSMISSION CAPACITY UTILIZATION	- ELIMINATE BACKHAULING	- HARDWARE, MANPOWER, CIRCUIT MILEAGE SAVINGS - INCREASE SYSTEM AVAILABILITY
NETWORK RECONFIGURATION	- CHANNEL REASSIGN IN THRU-GROUPS - REDUCE CIRCUIT ACTIVATIONS AND DEACTIVATIONS - INCREASE RESTORATION CAPABILITIES	- MANPOWER SAVINGS - INCREASED SYSTEM SURVIVABILITY
NETWORK FLEXIBILITY	- ELIMINATE RECHANNELIZATION - REDUCE RADIO BANDWIDTHS	- HARDWARE SAVINGS
AUTOSEVOCOM II AND TRI-TAC INTERFACES	- REDUCE COMPLEXITY OF INTERFACE - PERMIT AN/TTC-39 TO BE USED AT DESIGNED CAPABILITY	- HARDWARE SAVINGS
SYSTEM CONTROL OPERATIONAL BENEFITS	- PROVIDE LOOPBACK CAPABILITY - PROVIDE FOR UNATTENDED OPERATION OF DCS STATIONS	- HARDWARE, MANPOWER SAVINGS - INCREASE SYSTEM AVAILABILITY

The programmable multiplexer would provide multiplex and channel reroute capability in one unit thus requiring less hardware than separate units while providing greater flexibility. The work scope would be to design, develop, and test a programmable multiplexer based upon the attributes of the DRAMA multiplexer and the DNC.

SECTION 3

DCS DIGITAL TRANSMISSION SYSTEM

This section describes the digital transmission equipments which will make up the DCS Digital Transmission System and which are to be monitored by CPMAS. The digital transmission equipments include the DRAMA Radio and Multiplex equipment, Digital Applique Unit (DAU) FM Radio equipment, Frankfurt-Koenigstuhl-Vaihingen (FKV) Radio and Multiplex equipment, Satellite Terminal Interface equipment, Encryption equipment and the Group Data Modem.

A Digital Transmission System Model which provided a framework for CPMAS designs and analyses is described. The Digital Transmission System Model is based upon the planned DCS Digital Transmission System for Europe, government documents describing DCS digital transmission plans (e.g., DCEC TR-12-76, DCEC TR 3-74) and the Automated Technical Control System Description.

The model provides a digital transmission system which includes a nodal control area, a large nodal station, terminal and repeater stations, a satellite terminal interface and several radio system alternatives. The model is sized to insure that CPMAS designs can meet all requirements placed upon them when they are applied to any portion of the DCS Digital Transmission System. The model further includes multi-link routes and various terminations (e.g., 4 kHz (PCM derived), async digital channels, digital groups, and 16 Kb/s digital subchannels).

The Digital Transmission System Model is described in Section 3.1. Descriptions of each of the DCS digital transmission equipments which will be monitored by CPMAS are given in Appendix A.

CPMAS design characteristics were evaluated in the context of the Digital Transmission System Model. Sensitivity analyses also investigated the effect of varying transmission model and CPMAS design parameters on CPMAS designs. Sensitivity analysis parameters are summarized in Section 3.1.4.

3.1 Digital Transmission System Model

The Digital Transmission System Model shown in Figure 3-1 is a nodal area model which includes the different network characteristics and station types encountered in the Planned DCS Digital Transmission System. The model provides a multi-link transmission network, a large nodal station, repeater, branching repeater and terminal stations and a satellite terminal interface.

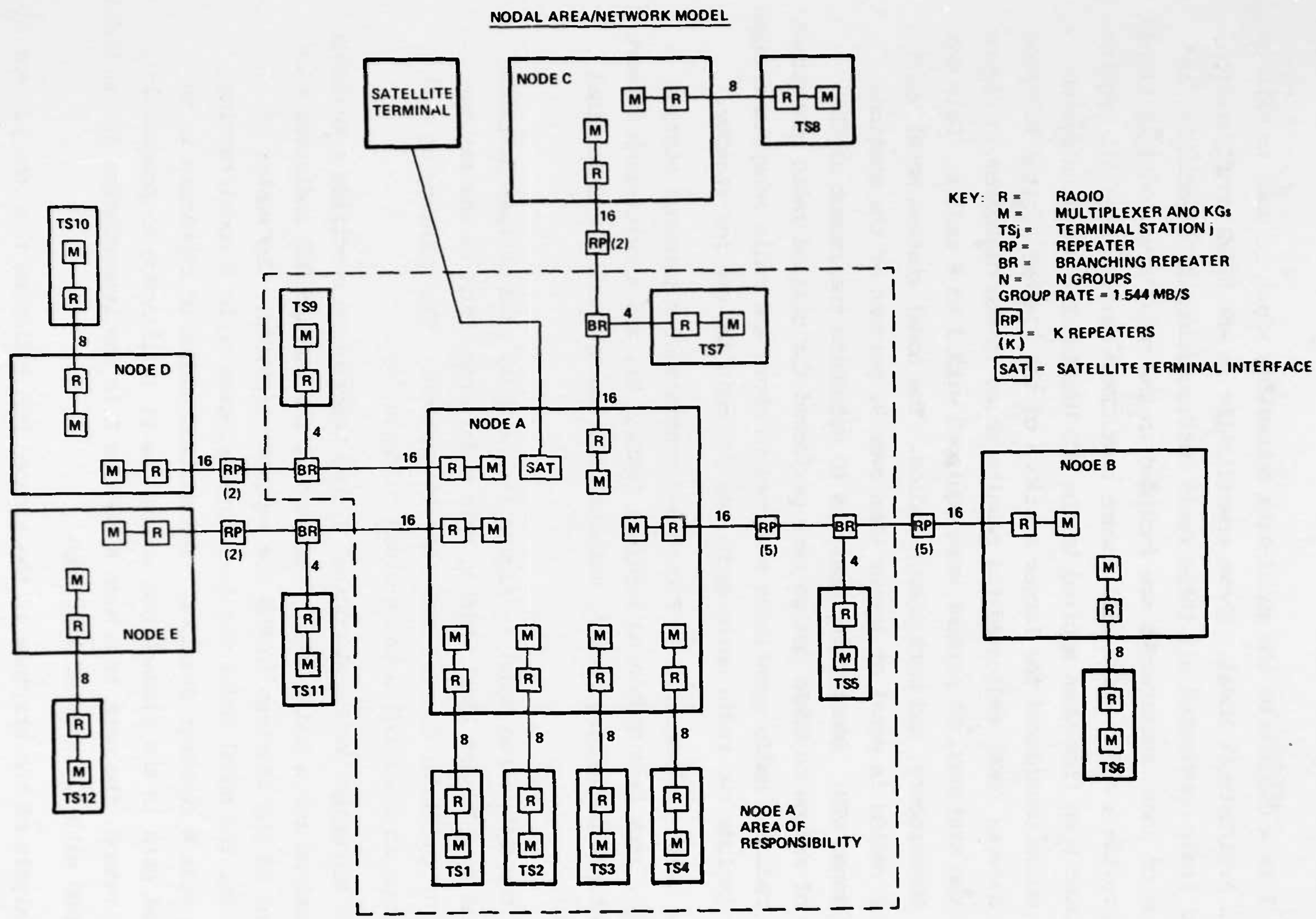

FIGURE 3-1. DIGITAL TRANSMISSION SYSTEM MODEL (NODAL AREA)

Figure 3-2 is a diagram of the multi-link subnetwork which is used to make up the Nodal Area/Network Model. Shown specifically is the DRAMA Configuration. The CPMAS Study considered all three radio configurations DRAMA, DAU-FM, and FKV. Four of these subnetworks are included in the nodal area model in Figure 3-1, to provide a model which will insure that CPMAS designs meet all requirements placed upon them when applied to the DCS Digital Transmission System. Analysis which considered the larger stations of the Planned Digital European Backbone Network (DEB) indicated the results shown in the histogram in Figure 3-3. Of the stations, 85 percent were equipped with 3 to 6 radios. Only one station, Donnersburg, had more than 8 radios. The nodal station model which contains 8 radios is equal or larger than over 90 percent of the stations in the Planned DEB. Sensitivity Analyses to determine the impact of the quantity of radios on CPMAS design were performed for station radio quantities up to 16 radios. Radio quantities referred to above are radio subsystems which actually include two radio units each, one for main and one for standby.

The multi-link network in Figure 3-2 consists of a terminal station link (e.g., link from Node A to Terminal Station B), and a multi-link network (e.g., network connecting Noda A, Terminal Station A), Node B and Terminal Station C).

In the Nodal Area Model in Figure 3-1, a nodal area of responsibility is defined by a dashed line. Within this nodal area which is the responsibility of the Nodal Control there are 16 stations. The quantity of each station type in the nodal area is given in Table 3-1.

The Automated Technical Control System Description specifies a maxiumum of 16 stations for a nodal area. Analysis of the planned DEB indicates that 50 percent of the stations in DEB are repeater stations. The number of stations for the nodal model was therefore selected to be 8 nodal/terminal stations plus 8 repeater stations. The maximum number of repeaters in an internodal path in the planned DEB network is 11 (Hillingdon to Schoenfeld). For this reason, the path from Node A to Node B in the Transmission System Model is equipped with 11 repeater stations.

Analysis of the stations in the planned DEB indicated that the percent of Digroups terminated with first-level multiplexers was approximately 50, and thus 50 percent of Digroups in the Nodal Station Model (Node A in Figure 3-2)

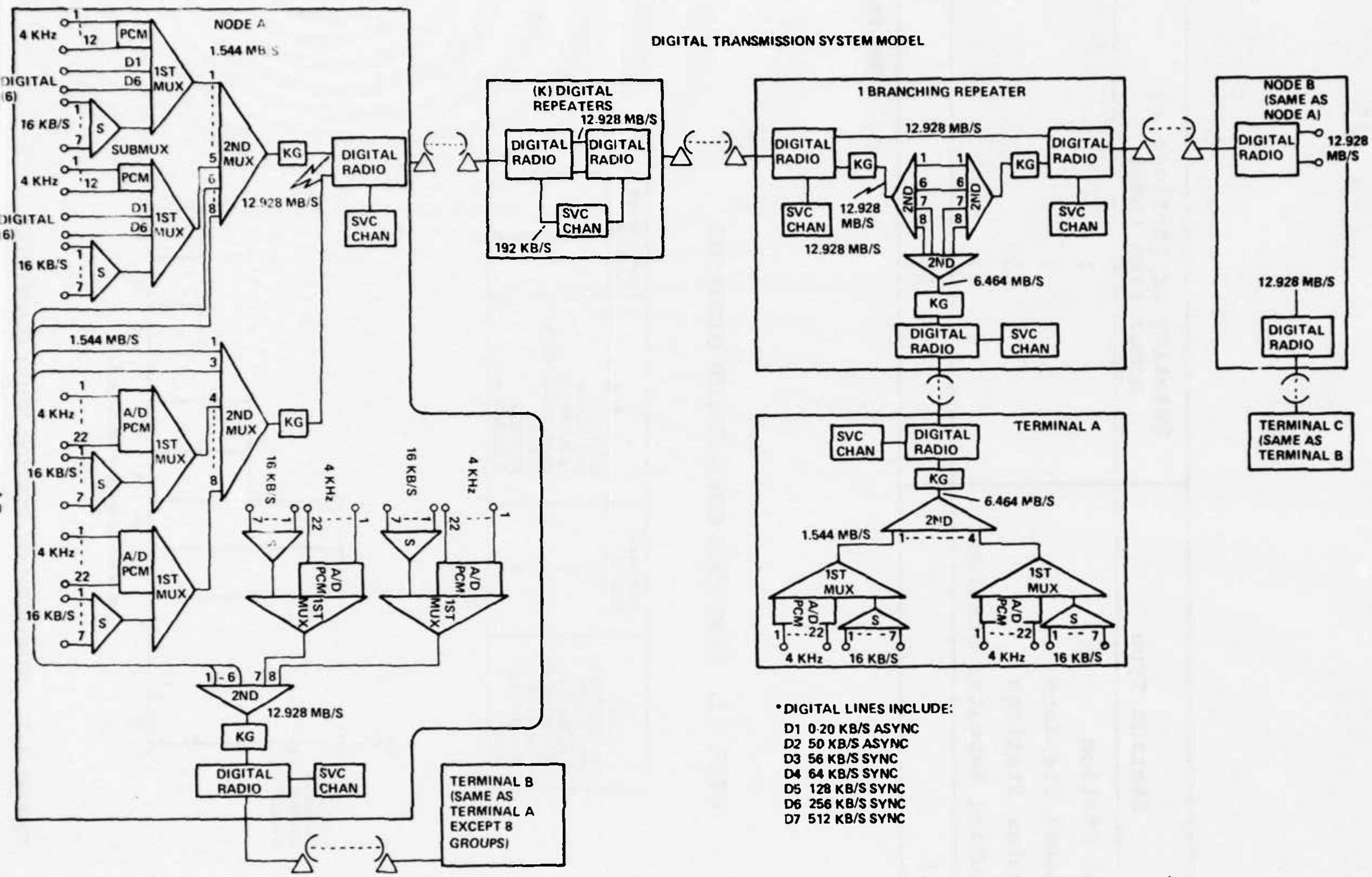

FIGURE 3-2. MULTILINK SUBNETWORK

Station Type	Quantity of Stations in Nodal Area Model
Nodal Station	1
Terminal Stations	7
Repeater Stations	5
Branching Repeater Stations	3
Total	16

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TABLE 3-1. NODAL AREA MODEL STATION QUANTITIES

SITE	MICROWAVE RADIOS	SITE	MICROWAVE RADIOS
HOHENSTADT	4	BANN	6
STUTTGART	4	HILLINGDON	3
LANGERKOPF	5	CROUGHTON	4
DONNERSBERG	10	MARTLESHAM HEATH	3
PIRMASENS	4	ADENAU	3
SCHOENFELD	3	FELDBERG	8
MUHL	6	KOENIGSTUHL	5

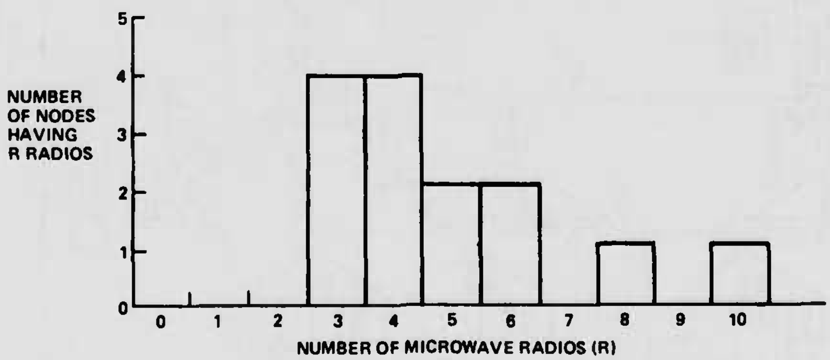


FIGURE 3-3. HISTOGRAM OF STATION RADIO QUANTITIES

are terminated with first level multiplexers.

3.1.1 Radio Systems

The Digital Transmission System Model includes three different types of radio systems, namely the DRAMA-type digital radio, the FM radio with Digital Applique Unit and the FKV radio. Figure 3-4 shows a link equipped with each of the first two radio system alternatives. The multiplex and KG equipments are the same for both of these radio systems since each radio can accept the same mission bit stream bit rate. These two radio systems can transmit/ receive two 12.9 megabit-per-second bit streams in the Digital Transmission System Model. The third radio system alternative, the FKV radio system, is shown in Figure 3-5. The FKV radio system uses the T14000 second level Multiplexer, CY104 first level (PCM) Multiplexers and T1WB1 Digital Multiplexers. Channel quantities for the different FKV multiplex configurations terminating 8 digroups are listed in the table in Figure 3-5 The FKV radio baseband signal is limited to 12.6 MB/S, half the maximum capability of the DRAMA and FM/DAU radio systems and cannot directly replace all radios in the Transmission System Model. Comparative Analyses for the FKV radio systems performed in the study adjusted radio and multiplex quantities to achieve a fair comparison of the FKV, DRAMA and FM/DAU radio systems.

The nodal area model contains 15 links and 4 interface links which terminate at another nodal area. The resulting number of radios within the nodal area model is 34. Sensitivity analyses were performed for nodal area radio quantities up to 128 radios. The ATEC System Description specifies a maximum of 64 links for a nodal area which implies a maximum of 128 radios.

Sensitivity Analyses related to the nodal area performed in the study used the parameters and ranges listed in Table 3-2.

3.1.2 Satellite Terminal Interface

The transmission model's Satellite Terminal Interface is shown in Figure 3-6. This interface is a planned cable interface to the Satellite Terminal Station where the cable is terminated by the MD920 modem's companion modem MD921. The Satellite Terminal Interface Multiplexers include the DRAMA First Level Multiplexer (TD1192) and the AN/GSC-24 Second Level Multiplexer. The

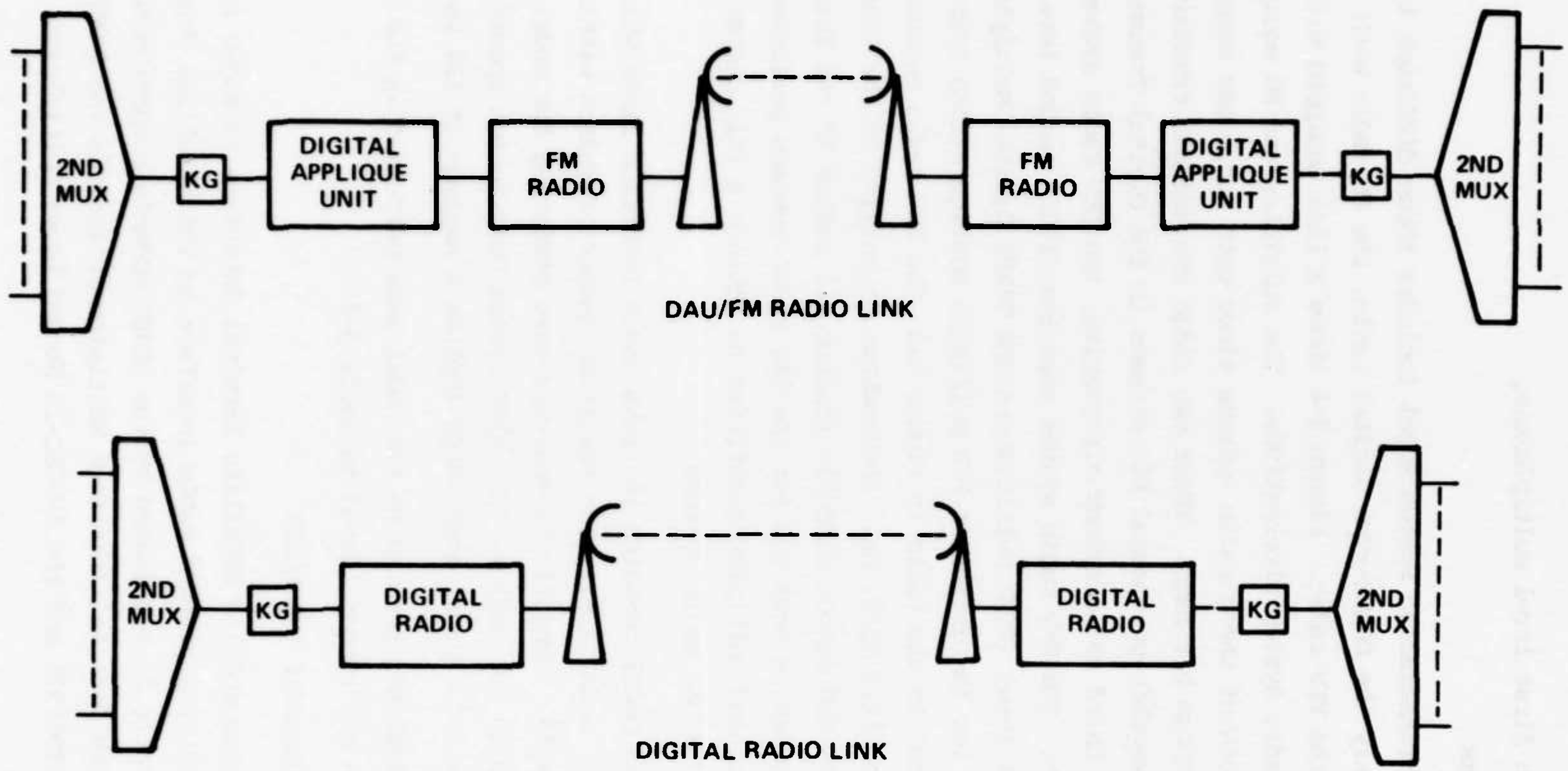
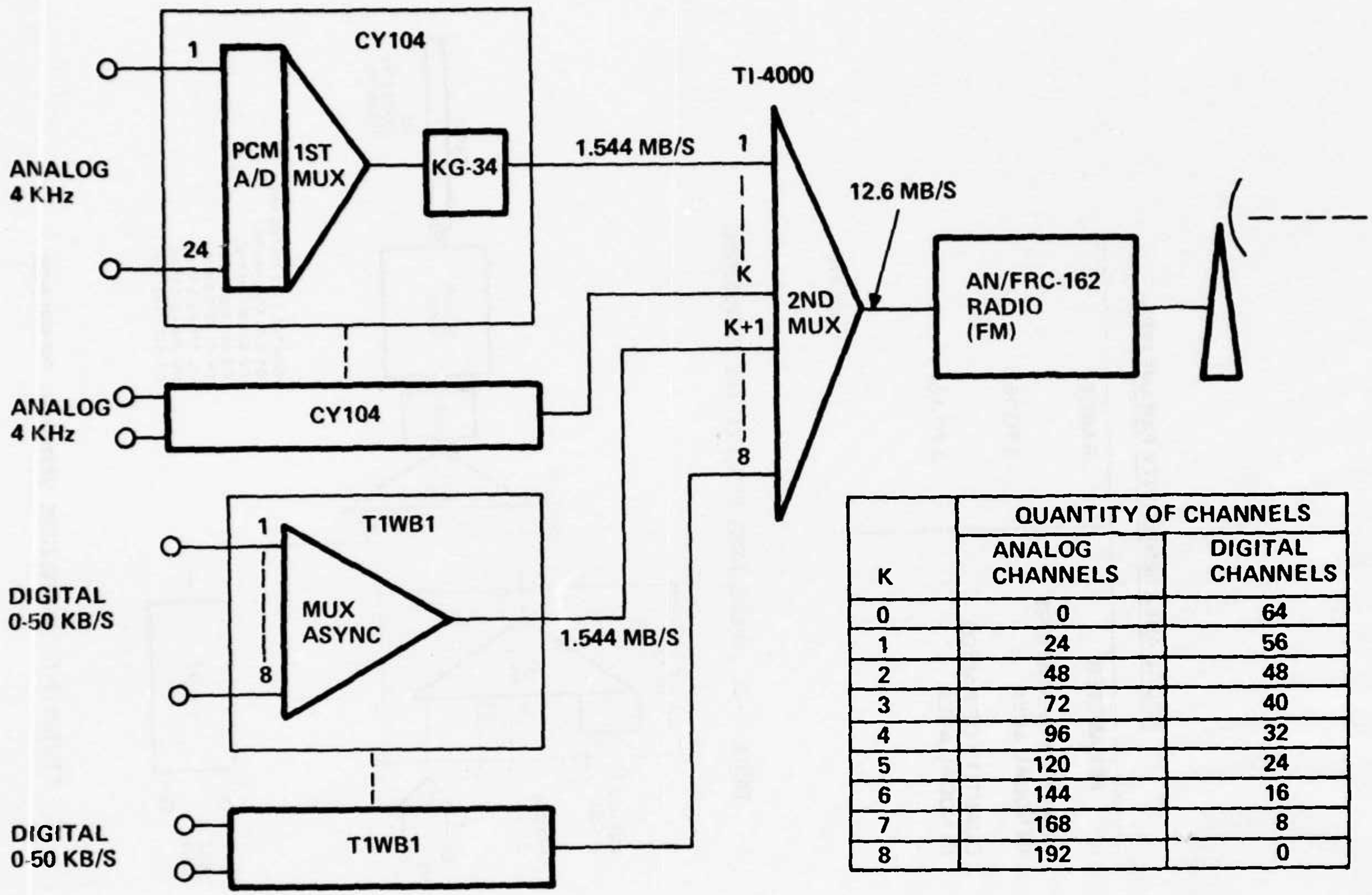


FIGURE 3-4. DIGITAL AND DAU/FM RADIO LINKS



K	QUANTITY OF CHANNELS: ANALOG CHANNELS	QUANTITY OF CHANNELS: DIGITAL CHANNELS
0	0	64
1	24	56
2	48	48
3	72	40
4	96	32
5	120	24
6	144	16
7	168	8
8	192	0

FIGURE 3-5. FKV MUX/RADIO SYSTEM

NODAL AREA SENSITIVITY PARAMETERS

PARAMETER	RANGE
QUANTITY OF STATIONS IN NODAL AREA	3 TO 16
QUANTITY OF RADIOS IN NODAL AREA	3 TO 128

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TABLE 3-2. NODAL AREA SENSITIVITY PARAMETERS

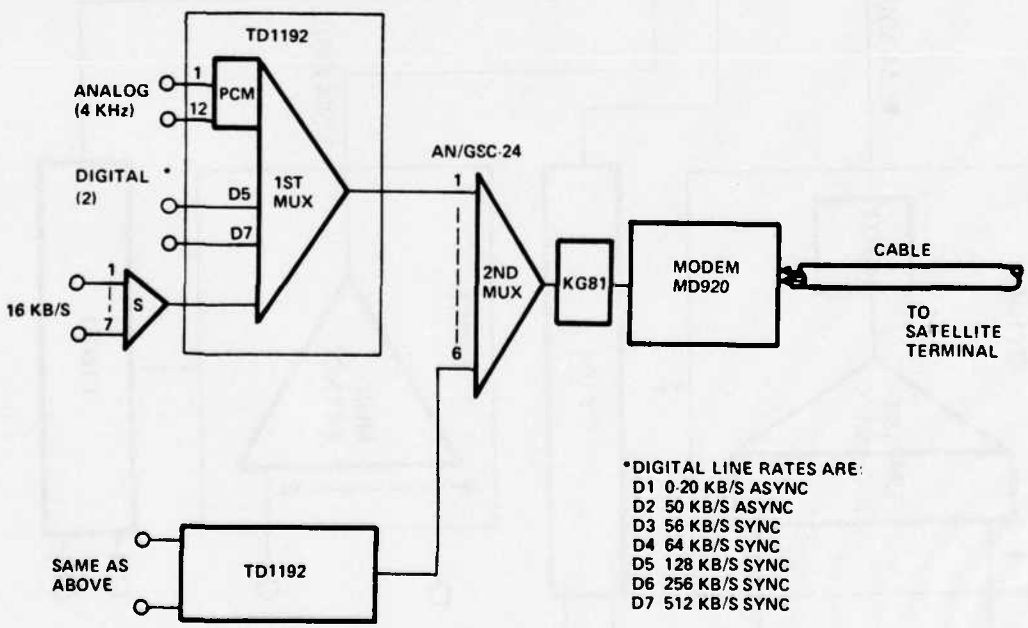

FIGURE 3-6. SATELLITE TERMINAL INTERFACE

CPMAS is responsible for the transmission equipments up to and including the MD920 modem. The Satellite Terminal Station and the Cable is the responsibility of the Satellite Terminal Technical Control. A microwave radio link interface to the satellite terminal is also possible. The microwave satellite terminal interface is identical to the terrestrial radio links already included in the transmission system model.

3.1.3 Nodal Station Model

The nodal station model (node A in the nodal area model) is shown in Figure 3-7. Each digital transmission equipment group refers to the radio/multiplexer equipment in the transmission system model subnetwork shown in Figure 3-2. Four of these equipment groups provide the eight radio/multiplexer subsystems of the nodal station model. CPMAS for digital transmission systems monitors these digital transmission equipments and the Satellite Terminal interface equipment. The 4-kHz analog lines and low-speed digital lines will be monitored by the analog ATEC subsystem; i.e., the AN/GYM-12 or AN/GYM-13 or functional equivalent designed for that purpose. The nodal station model characteristics related to CPMAS are summarized in Table 3-3.

Sensitivity Analyses related to the Nodal Station performed in the study used the parameters and ranges listed in Table 3-4.

3.1.4 Sensitivity Analysis Parameters

Many of the CPMAS design characteristics were evaluated using the digital transmission system model described in this section. However, it is essential to evaluate certain CPMAS characteristics at extreme transmission system parameter values. Table 3-5 summarizes model sensitivity parameters and ranges which were used in the CPMAS study. The percentage of groups terminated with multiplexers is an important sensitivity parameter because it determines the number of first level multiplexers at a station and, thus, the number of alarms to be scanned.

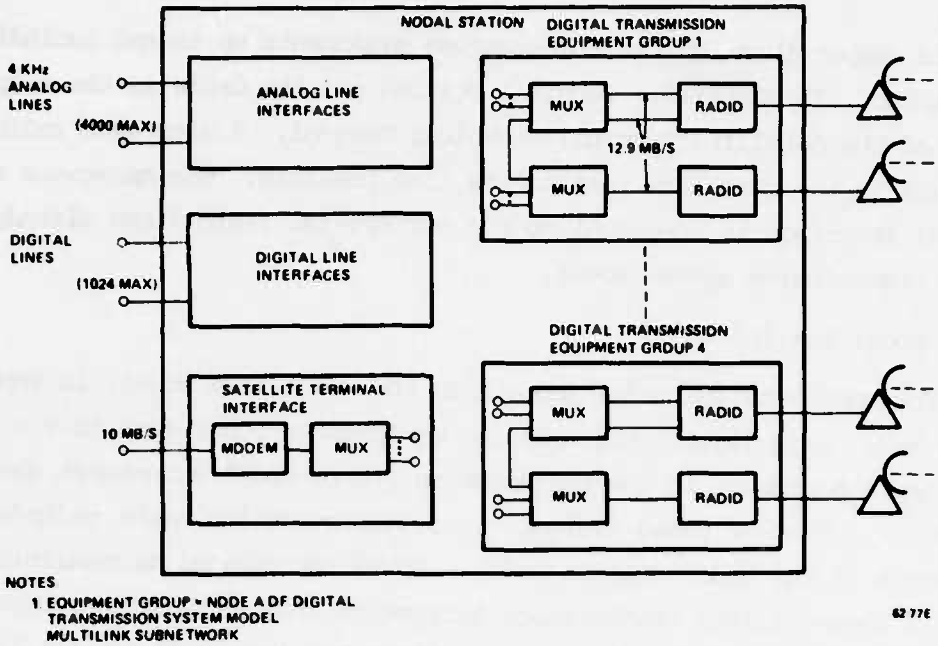

FIGURE 3-7. NODAL STATION MODEL

- **DIGITAL GROUPS AT NODAL STATION** 104
- **RADIOS AT NODAL STATION** 8
- **DIGITAL TRANSMISSION CHANNELS TERMINATED:**

	4 KHz (PCM DERIVED)	928
	16 KB/S (SUB MUX INPUTS)	378
	DIGITAL (1ST LEVEL MUX)	132
	TOTAL	1438

TABLE 3-3. NODAL STATION MODEL CHARACTERISTICS

Parameter	Range
Quantity of Radios	1-16
Percent of Groups Terminated with MUX	0-100%
Type of Radio	DRAMA/DAU/FM/FKV

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TABLE 3-4. STATION SENSITIVITY PARAMETERS

PARAMETER	RANGE
QUANTITY OF STATIONS IN NODAL AREA	3 TO 16
QUANTITY OF RADIOS IN NODAL AREA	3 TO 128
QUANTITY OF RADIOS AT A STATION	1 - 16
PERCENT OF GROUPS TERMINATED WITH MUX	0 - 100%
TYPE OF RADIO	DRAMA/DAU/FM/FKV

TABLE 3-5. MODEL SENSITIVITY PARAMETER SUMMARY

SECTION 4

CPMAS REQUIREMENTS

In this section the availability of the reference digroup and data/VF channel are evaluated for several CPMAS configurations. It was found that the digroup availability exceeds the DCS requirement for all CPMAS configurations considered. The data/VF channel availability does not meet the DCS requirements when performance assessment and automated fault detection/isolation are employed. However, when a trend analysis technique capable of predicting 20% of the radio failures is added, the data/VF channel availability exceeds the DCS requirement. The above analysis assumes equipment meeting DRAMA specifications. The effect of monitoring less than the DRAMA specified alarms is discussed and this effect upon data/VF channel availability presented. presented.

The preceding availability analysis was used to recommend a CPMAS system. Preliminary recommendations for performance assessment, fault detection/isolation, trend analysis, and corrective actions were made. These recommendations are such as to enable the DCS to meet or exceed the updated performance and availability requirements.

In Section 4.1 the DCS performance and availability requirements are discussed. The purpose of this discussion is to provide a yardstick by which the various CPMAS configurations can be gauged. Section 4.2 presents the results of an availability analysis relating system availability to the degree of CPMAS employed. The functional requirements for CPMAS that enable the DCS to meet its performance requirements are discussed in Section 4.3.

4.1 DCS AVAILABILITY AND PERFORMANCE REQUIREMENTS

Preliminary performance objectives for digital DCS transmission systems have been defined ("Digital Transmission System Design", DCEC report TR 3-74, March 1974") and updated ("DCS Digital Transmission System Performance", DCEC report TR 12-76). The DCS system requirements resulting from these reports are presented in this section.

4.1.1 DCS Performance Objectives

Preliminary performance objectives for Digital DCS transmission systems

have been defined ("Digital Transmission System Design," DCEC Report TR 3-74, March, 1974). These objectives were stated in terms of four performance measures, namely, bit error rate (BER), jitter, bit-count integrity (BCI), and availability. A fifth parameter, error-free seconds (EFS), was postulated as an additional performance measure.

Recently the performance objectives were updated ("DCS Digital Transmission System Performance," DCEC Report TR 12-76). This updating has resulted in the digital DCS transmission system objectives being specified in terms of six performance measures. They are: probability of a fade-outage, mean time between loss of bit count integrity, availability, link design (fade margin for line-of-sight (LOS), mean SNR for troposcatter), system gain, and error free data blocks.

The probability of a fade-outage for LOS links is defined as the probability that all diversity paths will be below the received signal level (RSL) corresponding to a 10^{-4} BER for longer than five seconds. Mean time to loss of BCI is specified as a percentage of fade-outages which result in a loss of BCI. Availability if the cumulative percentage of time that the system is in an outage condition, where an outage is defined as any of the following:

a. loss of path continuity for a period in excess of one minute,

b. error rate on either mission bit stream in excess of 10^{-6} for a period in excess of one minute,

c. fade-outage rate in excess of five per minute for a period in excess of one minute.

Fade margin is defined as the difference in dB between the non-faded RSL and the RSL required to obtain a 10^{-4} BER at the receiver output. System gain is defined as the difference between transmitter RF power output and required receiver input to obtain a 10^{-4} BER. Error free data blocks is the fraction of 1000 bit data blocks received without an error.

Table 4-1 presents the preliminary and updated performance objectives for the digital DCS transmission system.

It should be noted that fade margin and system gain are, in reality, link design specifications and as such will not be continuously measured during system operation.

TABLE 4-1. PERFORMANCE OBJECTIVES FOR THE DIGITAL DCS TRANSMISSION SYSTEM

PRELIMINARY OBJECTIVE (PER DCEC TR 3-74)			UPDATED OBJECTIVES (PER DCEC TR 12-76)		
1.	AVAILABILITY PER LOS LINK	= 0.9995	1.	PROBABILITY OF FADE-OUTAGE (LOS LINK)	$< 1.25 \times 10^{-5}$
2.	BIT-ERROR RATE PER LOS LINK	$= 5 \times 10^{-9}$	2.	SYSTEM GAIN (LOS LINK)	> 104 dB
3.	BIT-COUNT INTEGRITY FOR TOTAL SUBSYSTEM (MEAN TIME TO LOSS OF)	= 24 HOURS	3.	AVAILABILITY – REFERENCE DIGROUP – REFERENCE CHANNEL	 ≥ 0.9998 ≥ 0.999
4.	JITTER – MAXIMUM DEPARTURE PER LOS LINK	= 1/4 BIT INTERNAL	4.	BIT-COUNT INTEGRITY (LOS FADES RESULTING IN LOSS OF)	< 2%
5.	ERROR-FREE SECONDS (FOR 12,000 NMI CIRCUIT)	= 99.99%*	5.	FADE MARGIN (NOMINAL LOS LINK)	= 32 dB
			6.	ERROR-FREE DATA BLOCKS (1000 BIT DATA BLOCKS)	> 99%

*BEING CONSIDERED FOR DIGITAL DATA SERVICE.

4.1.1.1 Reference Digroup Availability

A DCS digital group (digroup) has a transmission rate of 1.544 Mbps. The DCA has placed performance and availability requirements upon a reference digroup. The reference digroup segment is shown in Figure 4-1. A reference digroup is defined as two second level multiplexers with associated bulk encryption equipment connected by three tandem RF links (three LOS links for a type A reference digroup or two LOS links and one tropo link for a Type B reference digroup).

The availability requirement shall be at least 0.9998 for the Type A reference digroup and 0.9997 for the Type B reference digroup.

The reference wideband data channel shall operate at 1.544, 3.088, or 6.176 Mb/s and shall be composed of appropriately strapped ports of the reference digroup transmission link. The performance of the reference wideband data channel shall be the same as that of the reference digroup.

4.1.1.2 Reference Data/VF Channel Availability

The DCA has placed performance and availability requirements upon reference data and VF channels. Performance characteristics of the reference data channel shall be as measured from the data submultiplexer channel input to the corresponding channel output of the data submultiplexer at the opposite end of the channel for 16×2^N Kb/s data channels (N=0,1, 2, 3), and shall be from the channel input of the Level 1 PCM multiplexer to the corresponding channel output of the Level 1 PCM demultiplexer at the opposite end of the channel for 50 Kb/s data channels.

In general, the VF channel characteristics are those of 64 Kb/s, u-law companded pulse code modulation with nominal 300-3400 Hz bandwidth and providing built-in E&M-lead supervisory signalling.

A reference channel (voice or data) is defined as two Level 1 PCM multiplexers connected by four tandem Type A reference digroups and one Type B reference digroup. This configuration is shown in Figure 4.2. The availability of the reference voice or data channel shall be at least 0.999.

4.1.2 CPMAS Considerations

In developing a CPMAS system, the DCS availability requirements must be

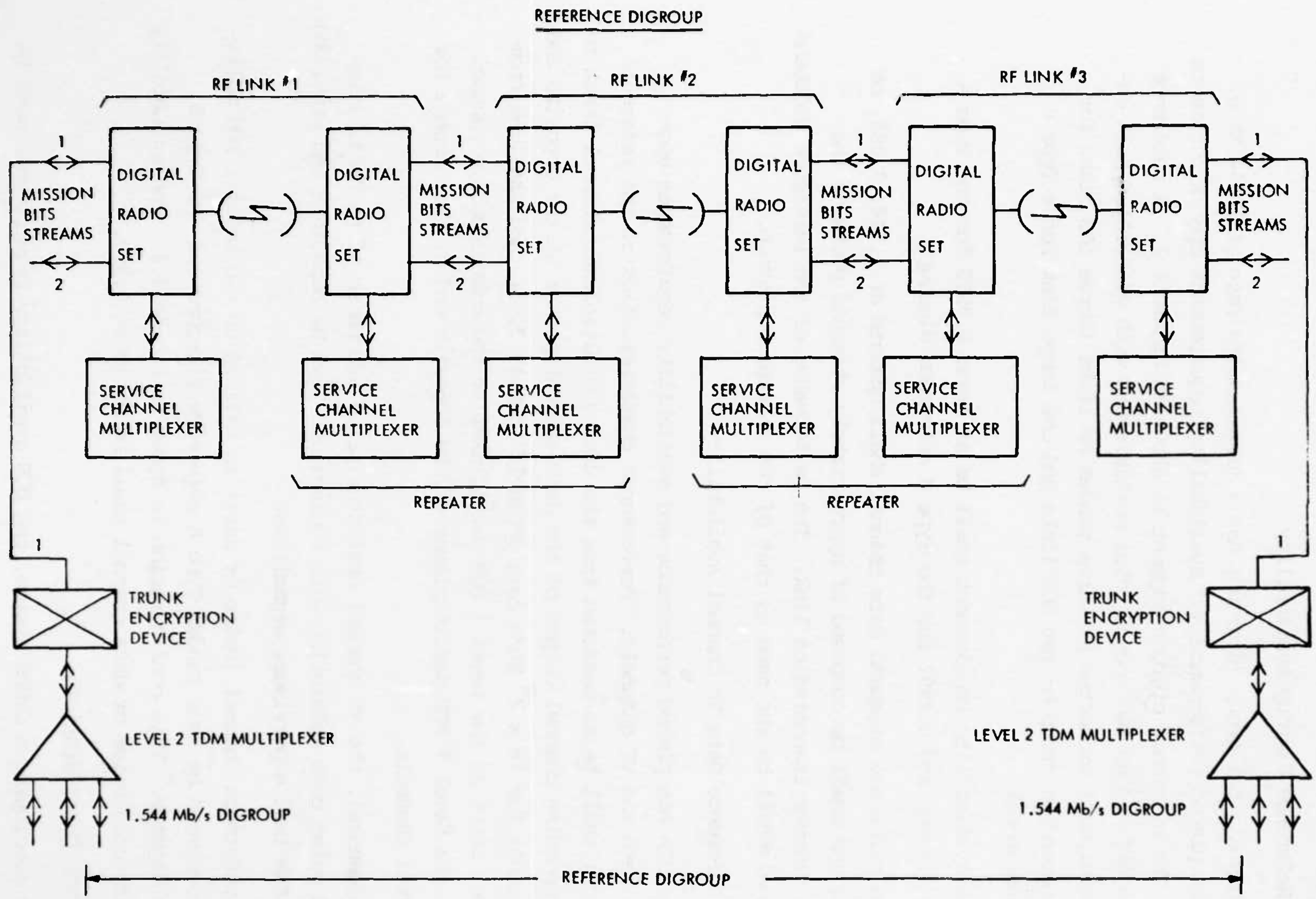

FIGURE 4-1. REFERENCE DIGROUP

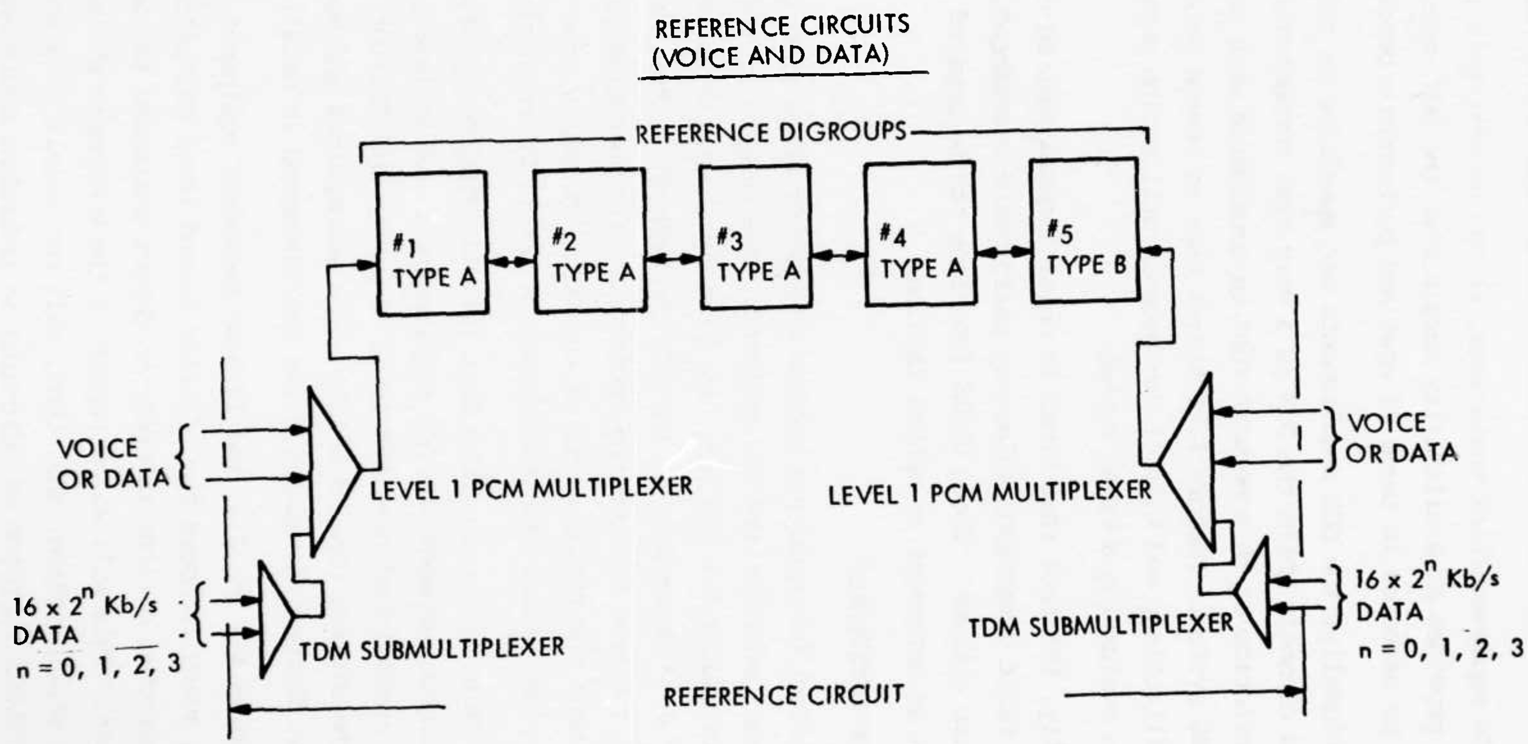

FIGURE 4-2. REFERENCE CHANNELS
(VOICE AND DATA)

considered. CPMAS provides the means by which these requirements are met.

Due to equipment/link variations, it may be desirable to develop a CPMAS system that provides an availability margin over the DCS requirements. This margin must be assessed in terms of cost and performance benefits.

Additionally, the DCS requirements are specified in terms of reference digroups and channels while the DCS is a very real communications network. The characteristics of this network must be considered when arriving at an optimum CPMAS system. Factors like travel time to remote sites, data/voice facility utilization, and time of day network utilization must be taken into account when evaluating a CPMAS system.

Finally, the fact that CPMAS is multi-faceted must be considered. CPMAS consists of fault detection/isolation, performance assessment, trend analysis, and corrective actions. These CPMAS functions can be applied in varying degrees and in an automatic or manual fashion.

4.2 CPMAS EFFECTIVENESS

The effect of employing various degrees of CPMAS upon the digroup and data/VF channel availability was analyzed. The results of this analysis are summarized in Tables 4-2 and 4-3. As shown in these tables the unavailability is presented as a percentage of the DCS requirement. Thus, unavailabilities less than 100% exceed the DCS requirements, while unavailabilities greater than 100% do not meet the requirements of the DCS. Naturally, the smaller the unavailability, the better the performance of the CPMAS configuration.

From Table 4-2 it is shown that for all CPMAS configurations, the digroup availability exceeds the DCS requirements. In addition, the CPMAS configurations investigated resulted in up to a 35% (91%-56%) of specification reduction in the digroup unavailability. The assumptions and methodology used to calculate the digroup unavailabilities are discussed in detail in Appendix B.

In Tables 4-2 and 4-3, the 24 hour redundant equipment check column indicates that every 24 hours the off-line second level multiplexers and digital radios are switched on-line in order to detect unalarmed failures in the off-line equipment. This will allow repair of the equipment while the on-line equipment is still working, and, thus, will not result in a communications outage. The CPMAS approach of switching in redundant equipment is undesirable

TABLE 4-2. CPMAS PERFORMANCE (DIGROUP UNAVAILABILITY)

MANUAL FAULT ISOLATION	AUTOMATIC FAULT ISOLATION	24 HR. REDUNDANT EQUIPMENT CHECK	2ND LEVEL MUX ASSESS.[1]	UNMANNED RADIO ASSESS.[1]	MANNED RADIO ASSESS.[1]	TREND ANALYSIS[2]	DIGROUP UNAVAILABILITY[3]
X							91%
X		X					80%
	X						85%
	X	X					73%
	X		100%				84%
	X		50%				84%
	X			100%			73%
	X			50%			79%
	X				100%		83%
	X				50%		84%
	X		100%	100%	100%		71%
	X		50%	50%	50%		78%
	X			50%		20%	57%
	X				50%	20%	60%
	X		50%	50%		20%	56%

NOTE 1: PERCENTAGE OF UNALARMED FAILURES DETECTED

NOTE 2: PERCENTAGE OF RADIO FAILURES PREDICTED BY TREND ANALYSIS

NOTE 3: PERCENTAGE OF SPECIFICATION (0.0002)

TABLE 4-3. CPMAS PERFORMANCE (CHANNEL UNAVAILABILITY)

MANUAL FAULT ISOLATION	AUTOMATIC FAULT ISOLATION	24 HR. REDUNDANT EQUIPMENT CHECK	2ND LEVEL MUX ASSESS.[1]	UNMANNED RADIO ASSESS.[1]	MANNED RADIO ASSESS.[1]	TREND ANALYSIS[2]	CHANNEL UNAVAILABILITY[3]
X							118%
X		X					110%
	X						112%
	X	X					102%
	X		100%				111%
	X		50%				111%
	X			100%			103%
	X			50%			107%
	X				100%		110%
	X				50%		111%
	X		100%	100%	100%		101%
	X		50%	50%	50%		106%
	X			50%		20%	89%
	X				50%	20%	93%
	X		50%	50%		20%	88%

NOTE 1: PERCENTAGE OF UNALARMED FAILURES DETECTED

NOTE 2: PERCENTAGE OF RADIO FAILURES PREDICTED BY TREND ANALYSIS

NOTE 3: PERCENTAGE OF SPECIFICATION (0-001)

since it results in the unnecessary tampering with a satisfactory operating system, can result in a 10% probability of losing bit count integrity during switching of the second level multiplexer, and requires manual intervention for the switching process.

Table 4-3 shows the data/VF channel unavailability as shown in this table using automated fault detection/isolation and performance assessment will not result in the channel unavailability meeting the DCS requirements. Including a trend analysis technique capable of predicting 20% of radio failures would then result in exceeding the DCS requirements. Thus, it can be concluded that trend analysis is necessary to meet DCS requirements. The assumptions and methodology used to calculate the data/VF channel unavailabilities are discussed in detail in Appendix B.

The results presented in Tables 4-2 and 4-3 are based upon equipment meeting the DRAMA specifications. One of the prime DRAMA specifications affecting communications availability is that at least 97% of all radio and second level multiplexer failures will be detected by BITE and will result in the automatic switch-in of the redundant equipment. Since other than DRAMA equipment will be part of the digital DCS, the sensitivity to varying the percentage of unalarmed failures was investigated. Figure 4-3 presents some results of this investigation. As shown in this figure, if 20% of the radio failures are unalarmed then the data/VF channel unavailability is more than twice (>200%) the DCS requirement. Thus, the effects of performance assessment and trend analysis upon system unavailability will be more pronounced if less failures are alarmed.

4.3 CPMAS FUNCTIONAL REQUIREMENTS

The purpose of this section is to define functional requirements for monitoring and assessing the digital DCS. Requirements will be placed upon the interoperability of the sector/nodal/station control hierarchial levels as well as the functional subsystems of CPMAS. Requirements for CPMAS are based upon firm requirements for maintaining the availability and performance of the digital DCS transmission system as discussed in Section 4.1.

The DCS System Control (SYSCON) is the means whereby DCS assets will be used to maintain/restore maximum DCS performance under changing traffic conditions, natural or man-made stresses, disturbances and equipment disruptions.

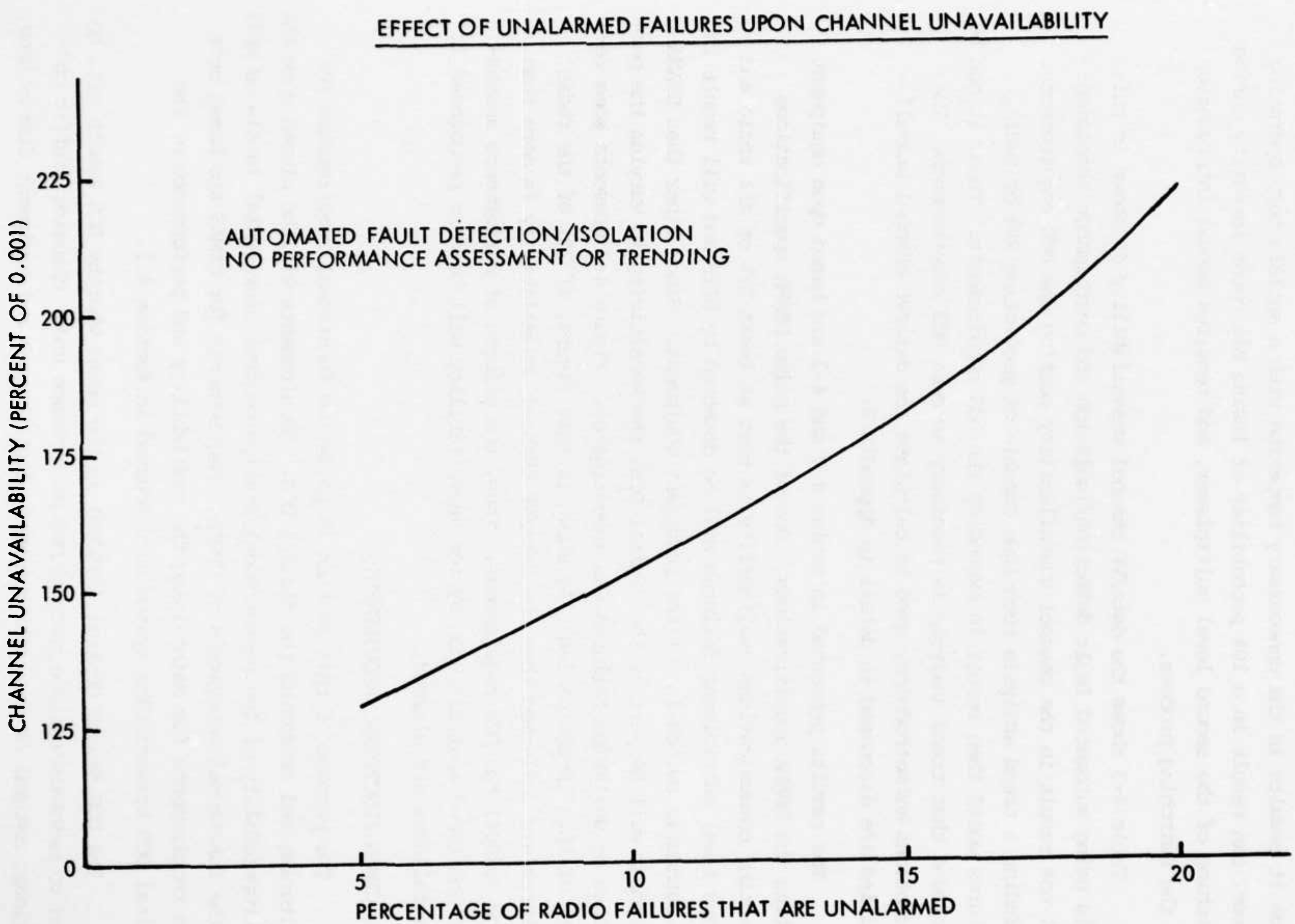

FIGURE 4-3. EFFECT OF UNALARMED FAILURES UPON CHANNEL UNAVAILABILITY

Basic aspects of system control include: timely acquisition of system performance data, facility and traffic load status, and service quality indications; the subsequent decision making; and the execution of real-time control actions plus the support of long range system management.

DCS SYSCON is structured within the following hierarchial levels:

Level One	Worldwide Control
Level Two	Theatre Control
Level Three	Sector Control
Level Four	Nodal Control
Level Five	Station Control

The Automated Technical Control (ATEC) System must be capable of responding to requirements allocated to it from other SYSCON functions and provide processor capacity to accommodate System Control.

4.3.1 CPMAS Description

The ATEC System will provide automation support to the sector, nodal, and station levels in those performance assessment and status monitoring functions related to maintaining the DCS transmission facilities. The Communications Performance Monitoring and Assessment System (CPMAS) addressed in this study is responsible for performing the ATEC functions associated with the digital transmission equipments. Figure 4-4 presents the CPMAS functions to be automated at ATEC.

Figure 4-5 illustrates the functional breakdown of the station/node CPMAS of digital transmission equipments. The station control functions include: Alarm Reporting Function (ARF) to detect equipment and facility change-of-state alarms; Parameter Converter Function (PCF) for measurement and conversion of specific transmission parameters; Communications Interface Function (CIF) for data interchange between the detection and measurement elements of the ATEC system, the Technical Controller, and the Nodal Control Subsystem; Controller Terminal Function (CTF) to provide the man-machine interface required for the Technical Controller to communicate to, and receive information from, the Nodal Control Subsystem (NCS) and other measurement functions; Wideband Digital Measurement Function (WDMF) for in-service measurement of wideband digital multiplex hierarchies, mission bit streams and equipments to in-

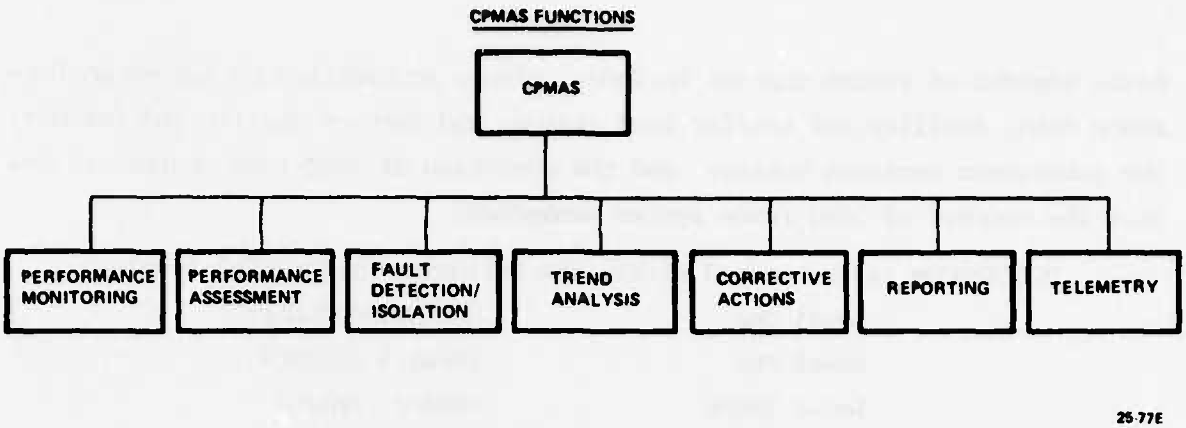

FIGURE 4-4. CPMAS FUNCTIONS

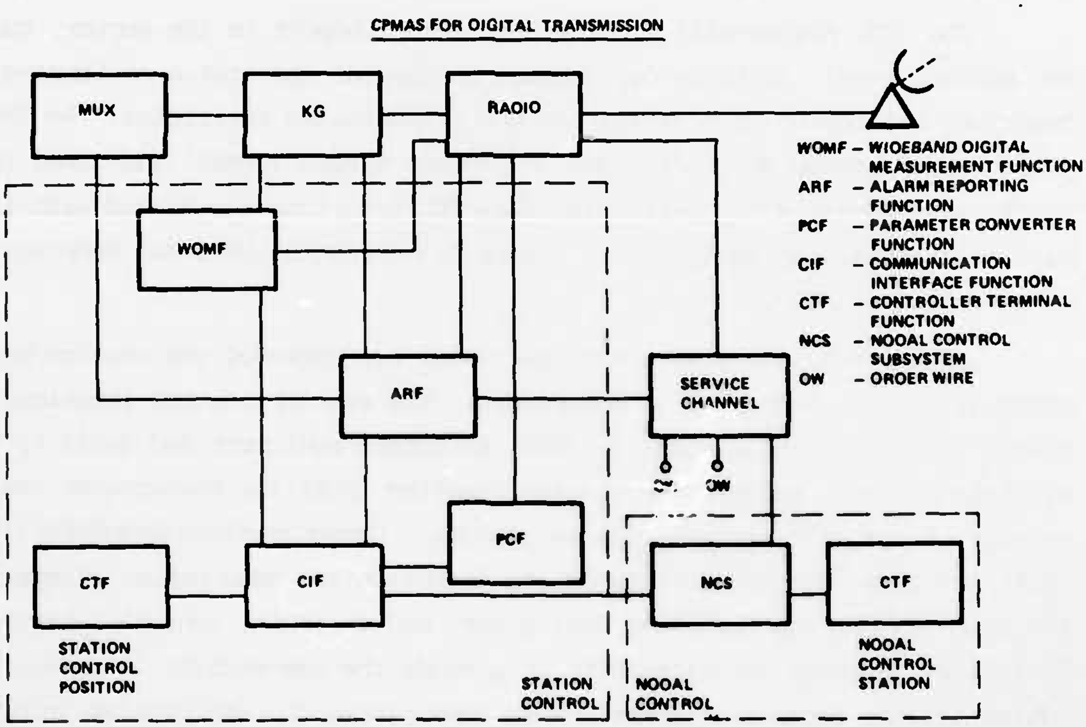

FIGURE 4-5. CPMAS FOR DIGITAL TRANSMISSION

clude parameter measurements, threshold comparisons, and alarming.

The nodal control is primarily tasked with concentrating and reducing data into meaningful results, correlating parameter measurements, identifying performance degradation, isolating faults, maintaining a dynamic data base of system resources and connectivity, and facilitating optimal alt-route and restoral actions. The nodal control requirements will be satisfied by the Nodal Control Subsystem (NCS). A CTF will provide the man-machine interface required by the Nodal Controller.

4.3.2 Sector/Nodal/Station Control Interoperability

Sector/Nodal/Station control are the three lowest hierarchical levels of DCS SYSCON. This section describes the requirements that interoperability of the three lowest SYSCON levels places upon the performance monitoring and assessment of digital transmission systems. SYSCON will be configured to provide for execution of restoral and reconfiguration actions at the lowest hierarchical levels and reporting to the highest levels of the hierarchy.

The Sector/Nodal/Station control interoperability requirements will be examined for their impact on performance monitoring and assessing the digital DCS transmission system. Some areas where the interoperability requirements may impact CPMAS are: telemetry budgets, message formats, message priority, data base management, and CPMAS processing capability.

The Sector/Nodal/Station control interoperability is defined in the Baseline Requirements Document and summarized in Figure 4-6. As shown in Figure 4-6 direction, coordination, and communication interfacing are performed at the higher hierarchical levels; and information and parameters/status data flows upward in the hierarchy. The Sector/Nodal Control interoperability requirements are:

a. The Sector Control Subsystem (SCS) correlates link status information from adjacent SCSs and facilities under its jurisdiction, and notifies NCSs under its jurisdiction.

b. SCS will transmit restoral and alternate routing plans to NCSs. The SCS will coordinate information received from NCSs regarding implementation of restoral and alternate routing.

c. The SCS will maintain and display the complete system connectivity

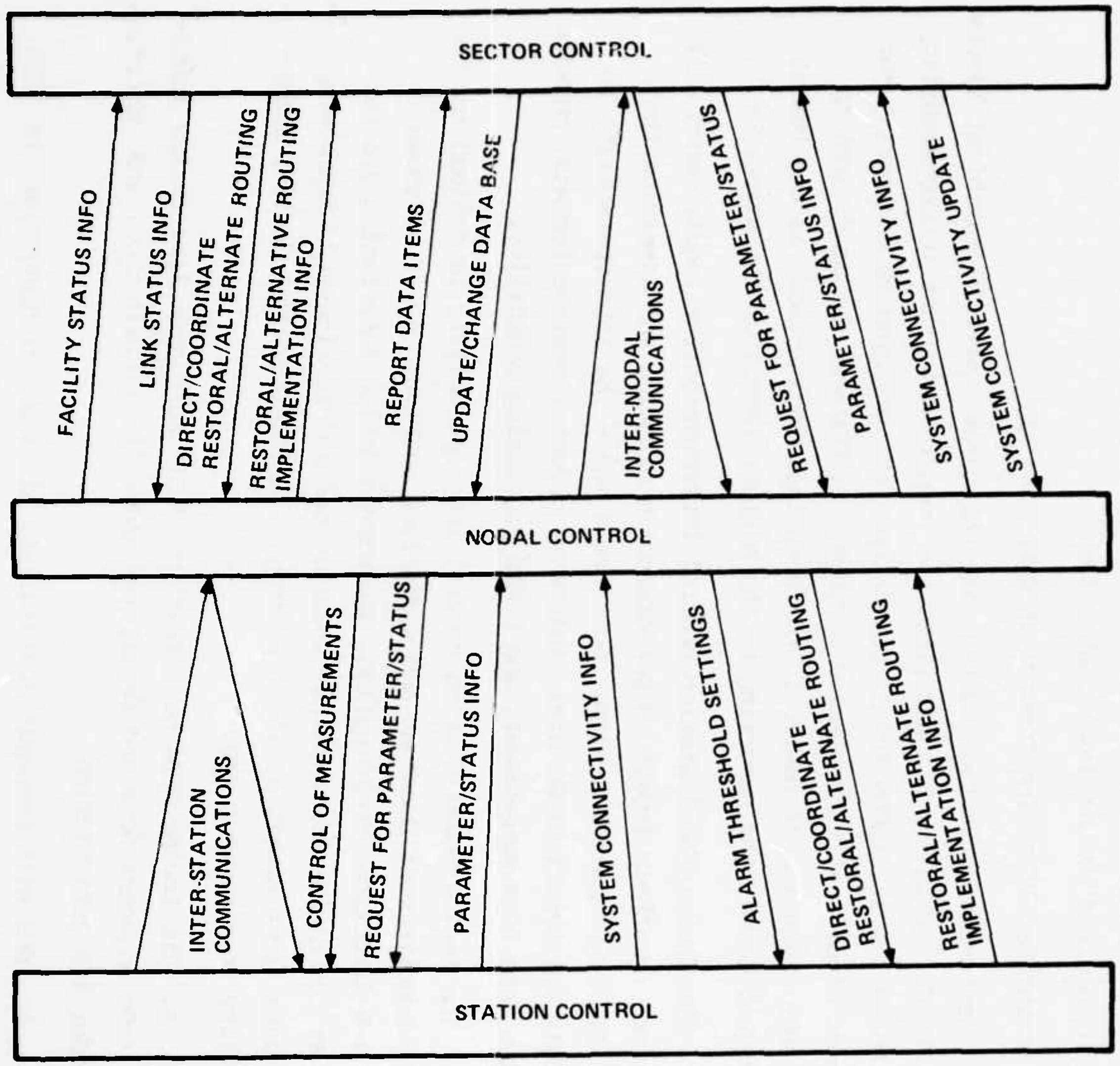

FIGURE 4-6. SECTOR/NODAL/STATION INTEROPERABILITY

information for the entire theatre. The NCS shall provide the connectivity information and the SCS shall issue a data base update message to the NCS.

d. SCS shall possess an automated capability to update/change the data base of all subordinate NCSs. The NCSs shall provide data items for reports.

e. The SCS shall provide the communication interface between NCSs within a sector by monitoring and coordinating the interchange of messages between NCSs.

f. The SCS shall have the capability to request parameter values and status information from any ATEC equipment via a subordinate NCS.

The Nodal/Station control interoperability requirements are:

a. Capability of the NCS to coordinate status information received from the SCS with the status information received from subordinate stations within the NCSs jurisdiction shall be provided.

b. Capability to transmit directed actions to station level Technical Controllers based upon restoral and alternate route plans shall be provided. The NCS will be notified of the results of station level actions.

c. The NCS shall provide the capability to maintain the data base of all subordinate Measurement Acquisition Subsystem (MAS) elements.

d. The NCS shall provide the capability to request that subordinate MAS elements obtain specific parameter measurements on selected communication links, trunks, and/or channels at predetermined time intervals during the normal scan and to store the resultant values for display upon request.

e. Fault isolation algorithms will be initiated either manually or by alarm conditions detected by MAS elements and reported to the NCS.

f. The NCS will be capable of controlling station level functions.

g. Capability to interface individual sets of MAS elements located at separate DCS stations, will be provided.

In addition to the above interoperability requirements, a stand-alone capability must exist whereby each level is capable of operating without the next higher level. It is considered operationally acceptable to fall back into a degraded mode of operation when the next higher level is inoperative. If the NCS is inoperative, the station level equipment must be able to stand alone using local I/O control devices. Whenever the MAS is disconnected from the NCS, the station level Technical Controller will be capable of local control of all MAS elements. A similar requirement exists for the NCS when the Sector Control Subsystem is inoperative.

4.3.3 Nodal Control Subsystem

The Nodal Control Subsystem satisfies the nodal control requirements. Before proceeding to the CPMAS functional requirements, a brief discussion of the NCS processing requirements will be presented. The Nodal Control Subsystem is primarily tasked with concentrating and reducing data into meaningful results, correlating parameter measurements, identifying performance degradation, isolating faults, maintaining a dynamic data base of system resources and connectivity, and facilitating optimal altroute and restoral actions. Additional responsibilities include reporting to Sector Control, coordination and control of station level actions, providing summary statistics, execution of specific test procedures, and identification and transfer of system and network problems to Sector Control. No measurements are made at this level.

The impact of Nodal control responsibilities upon NCS processing are:

a. Each NCS will store the complete system connectivity information for all DCS transmission facilities within its sector. Capability to display/change this data base must exist. The system connectivity data base will include route, link, trunk, channel and subchannel records. A loadable copy with changes will be available.

b. The NCS will maintain restoral and alternate route plans. A means of assessing the feasibility of implementing a planned alternate route or restoral action must exist.

c. The capability to store a minimum of 25 measurement results and associated statistics for up to 25 monitor points will be provided.

d. Capability to store and correlate status information for up to

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AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL--ETC(U)
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15 links will be provided.

e. Each NCS will provide the capability to store selected report formats, automatically enter data items provided by MAS elements, and display the format upon request. The capability to make a hard copy of the completed report and transmit the report will also be provided.

f. The NCS will provide the capability to acknowledge and issue commands to subordinate MAS elements.

g. The NCS shall have the capability to store fault isolation and performance assessment algorithms.

h. The NCS will provide the capability to maintain a 24-hour nodal event log and to accept external entries into the log.

i. Capability will be provided for the NCS to store the status of all equipments at each of a maximum of 16 DCS stations and up to 15 links per station.

j. The NCS shall maintain a Master Faults List with the capability to remove an entry and place it on a Subordinate Fault List.

k. Each NCS will be capable of interfacing with one Sector Control Subsystem and 64 Telemetry Channels maximum.

l. Capability of the NCS to interface with the controller terminal will be provided. The capability will exist for four slave terminals to be added at the NCS.

4.3.4 CPMAS Subsystems Functional Requirements

Figure 4-4 presented the CPMAS functions to be automated by ATEC. In this section the performance requirements for these functions will be discussed. The purpose of this discussion is to present the baseline requirements and allow an objective selection of the various alternatives for performing each of these CPMAS functions. The requirements will be presented in such a manner as to allow the greatest flexibility in selecting an alternative, while being specific enough to be able to determine if the proposed alternative meets the requirement.

The availability analysis of the previous section was used to recommend

a CPMAS system. Preliminary recommendations for performance assessment, fault detection/isolation, trend analysis, and corrective actions are made. These recommendations are such as to enable the DCS to meet or exceed the updated performance and availability requirements as stated in Section 2.

4.3.4.1 Fault Detection/Isolation

A fault is an abnormal condition resulting in a loss of system performance, a significant degradation in system margin, or a loss of a standby (or redundant) subsystem. The purpose of the Fault Detection/Isolation CPMAS function is to detect the occurrence of the fault, isolate the fault as to its cause, and report the results for corrective actions.

Faults can be categorized as two generic types: Intermittent faults (e.g., impulsive noise, fast fade) and hard faults (e.g., equipment failure, slow fade), Intermittent faults are to be examined as a possible precursor of a hard fault or to isolate fault external to the transmission equipment, for example, intentional jamming or faulty shielding of electric motors. Hard faults by their very nature imply a loss of system capability and are of more immediate concern to the Technical Controller. Hard faults can be further categorized as to the extent (e.g., supergroup, digroup, channel) of system degradation and as to their potential for system outage. For example, a hazard condition (HAZCON) exists if another like failure would result in the loss of at least a group or digroup.

The detection of a fault can be after-the-fact as indicated by equipment alarms, frame errors, subscriber complaints, etc. or before-the-fact using performance assessment measurements, trend analysis, etc.

The requirements for the Fault Detection CPMAS function are:

a. Performance assessment measured out-of-specification must be detected and reported to the NCS within TBD (~1 minute).

b. The change of status of all equipment and station alarms must be detected.

c. The means to process user complaints will be provided.

d. Redundant/standby equipment or subsystems will be checked periodically to detect faults in off-line equipments.

Once a fault has been detected, it must be isolated as to its location. Fault isolation is a resident software package located within the SCS or NCS. Associated with this package is the capability to command MAS elements to retrieve parameters and to command the insertion of test signals. The requirements for the Fault Isolation CPMAS function are:

a. Fault Isolation algorithm can be activated manually or automatically by alarm conditions. Fault isolation processing shall be automatic.

b. A fault shall be indicated on the Nodal Control panel within 30 seconds as a major or minor alarm for a particular site.

c. Fault isolation processing time is dependent upon the number of faults. One fault shall be isolated in less than two minutes.

d. Intermittent faults shall be isolated as to time of fault and probable cause.

e. Fault isolation shall be capable of coordinating activities on DCS links, trunk/circuits that cross jurisdictional boundaries and shall be capable of handing over fault isolation responsibility to a SCS or another NCS.

f. Isolation of redundant/standby equipment failures shall be performed. However, no switching of redundant/standby equipment for fault isolation shall be performed unless manually commanded (man-in-the-loop).

4.3.4.2 Performance Assessment

The MAS element associated with performance assessment of the wide-band digital multiplex hierarchies, mission bit streams and equipments is the WDMF as illustrated above by Figure 4-5.

Requirements for performance assessment have been determined. These requirements reflect the availability analysis of Section 4.2.

The performance assessment functional requirements are:

a. Assess the quality of the digital transmission signals by measuring or estimating a sufficient set of performance measures.

b. Assess the performance of digital transmission equipment.

c. For DRAMA equipment CPMAS must detect at least 50% of unalarmed

radio failures. No additional assessment isrequired for the DRAMA multiplexers.

d. Failure/use of the performance assessment MAS element will not degrade the transmission system.
e. Off-line equipment will be periodically assessed.
f. In-service performance assessment will be used.
g. Performance assessment shall provide fault detection/isolation information by assessing segments of a circuit.

These recommendations reflect the conclusion that assessing the second level multiplexer has a negligible effect upon availability (see automatic fault detection/isolation with 50%, 100%, and no second level multiplexer assessment) and that detecting unalarmed radio failures is linearly related to unavailability. Performance assessment of unmanned radios alone should be considered since radio failures at unmanned sites is one of the dominant contributors to unavailability.

4.3.4.3 Performance Monitoring

Performance monitoring is the CPMAS function associated with the extraction/conversion of parameters and with the monitoring of equipment/system status. The performance monitoring function is functionally represented in Figure 4-5 above by the ARF and PCF. The CPMAS performance monitoring function has the requirement of extracting the required signals and converting them into a format compatible with the other CPMAS functions. The signals must be sensed at the proper rate, duration, and accuracy and without disrupting (or degrading) the normal operation of the system. Thus, the requirements placed upon the CPMAS performance monitoring function will strongly depend upon the parameters being monitored.

Some data (e.g., equipment status alarms, Received Signal Level (RSL), etc.) must be monitored on a continuous basis and requires immediate monitor response. Those data involving the integrity of the mission bit stream fall into that category. Other data (e.g., fuel supply level, etc.) required upgrade at longer intervals and relatively slow response is acceptable.

Accuracy of CPMAS data is related to several factors:

a. Nature of the parameter monitored.

b. Resolution of the monitor function.

c. Capability of CPMAS response.

For example, an alarm for off-frequency operation, while requiring moderate accuracy, would not demand the precision that an analog readout of frequency error would require. These factors affect accuracy of monitors, reporting functions and control responses.

In addition to the above functional and performance requirements, the requirement to accept external commands to monitor a specific parameter must be incorporated in the MAS elements.

4.3.4.4 Trend Analysis

The primary functions of the trend analysis are to store selected parameter histories and to process this data so as to predict future system performance. Trend analysis will also be responsible for alarming impending component degradations.

As shown in Tables 4-2 and 4-3, trend analysis is necessary to meet the DCS availability requirements. The trend analysis requirements are:

a. Trend analysis shall provide parameter history storage.

b. Trend analysis shall perform the processing to predict future system performance and estimate time to cross predetermined thresholds.

c. Trend analysis shall predict greater than 20% of radio failures.

d. Predicted radio failures will have a mean lead time of twenty (20) to three hundred (300) hours.

4.3.4.5 Telemetry

The following is a list of the functional requirements of the telemetry subsystem:

a. Convey to the CPMAS processor located at the TCF analog parameter data (e.g., signal levels, noise measurements, etc.) relating to site operation and maintenance. This data is collected at both manned and unmanned sites on a regular basis.

b. Convey to the CPMAS processor at the TCF system status and alarm

conditions (e.g., carrier group alarms, primary power supply failures, etc.) which are monitored and stored at each site. This data may be collected on a regular basis, as changes in status occur, or a combination of both.

c. Convey framing, control, and test information required for monitoring synchronization, bit error rates, and other performance parameters.

d. Convey commands required for operation, maintenance, and/or tests.

The operational commands would relate to such functions as:

1. Initialization of telemetry system
2. Disabling of a data channel or subchannel
3. Loopback
4. Testing of local alarms
5. Ordered rather than automatic switch-over to standby equipment
6. Exercising of standby equipment
7. Calling for data from the local data base or sensors
8. Resetting of remote alarm registers

The technical requirements of the telemetry subsystem are summarized as follows:

a. Utilization of a 64-Kb/s subchannel of the service channel, per DRAMA, DAU/FM specification. (4-KHz analog telemetry channel for FKV).

b. Drop and insert capabilities at each site.

c. Analog parameters transmitted on a regular basis, as required by the trending and performance assessment subsystems.

d. Alarms and system status conditions monitored and changes transmitted.

e. Each station connected to its associated nodal control via a dedicated communications channel.

f. Error control capability.

g. Encryption of the telemetry channel must be possible.

Throughput and time requirements will dictate the channel baud rates. Circuit requirements between the nodal levels and subordinate measurement

elements must be minimized.

4.3.4.6 Corrective Actions

After the performance assessment, fault detection/isolation, or trend analysis CPMAS functions have detected or predicted and isolated a fault, the corrective action CPMAS function is responsible for correcting the fault and restoring service. For those fault that require repair of failed equipment to restore service, corrective action consists of notifying the technical controller and maintenance of the source and nature of the trouble.

Sometimes service can be restored prior to repairing the failed equipment. This arises when a failed on-line equipment can be switched off-line and the redundant equipment switched on-line. DRAMA second level multiplexers and radios are redundant and are automatically switched on-line by monitoring BITE alarms. For failures that are not alarmed, the failed equipment remains on-line. The corrective action would then consist of switching in the standby equipment. It is recommended that this switching be remotely commandable by the nodal controller.

In addition, the digital DCS will contain trunk encryption devices with associated crypto by-pass equipment. It is recommended that insertion of the crypto by-pass be remotely commandable when the failure has been isolated to the crypto.

Rapid restoration of service following an interruption (not automatically corrected) requires the proper execution of a sequence of procedures which culminate in the corrective actions taken by the technical controller. The sequence of procedures can be grouped into three general categories or phases as follows:

a. Fault detection	Corrective
b. Fault isolation	Maintenance
c. Corrective actions/service restoral	Phases

The actions taken by the controller to restore service will obviously be a complex function of the information gathered in the fault detection and isolation phases. However, given the system performance objectives (see

Section 4.1) and the corresponding time constraints on the corrective maintenance actions, the decisions and actions of the controller must provide the quickest method of restoral. In response to this need, CPMAS provides effectivie means for achieving the objective of minimizing the time required to complete the three phases of corrective maintenance. It accomplishes this by processing fault detection/isolation data either automatically or semi-automatically under the guidance of the technical controller.

In a general sense, there are only two options available to the technical controller with respect to restoring service following an outage. Assuming that the source of the problem has been isolated, the technical controller can either reroute the affected circuits around the troubled area or arrange for the appropriate maintenance personnel to repair the faulty equipment in a timely fashion. The criterion by which he chooses between the two alternatives, reroute or repair, is established by the DCA. As described in DCAC-310-70-1, if a fault cannot be corrected in a reasonable period of time, the technical controller is to reroute or restore in accordance with established restoration priorities, pending completion of repairs.

4.3.4.7 Reporting

The reporting CPMAS function will be required to automate the record keeping functions of SYSCON. The general procedures and guidelines to be followed by the technical controller in fulfilling the record keeping functions are well established (DCAC 310-55-1). Through the use of a record keeping software package many of the record keeping functions will be automated. Data stored in the record system will be analyzed, formatted according to report type, and displayed to the controller for verification. Records and logs of a narrative nature will also be able to utilize data stored in the record system for scheduling and reference purposes.

Operational direction and control actions in ATEC generally flow downward in the hierarchical DCS SYSCON system, whereas reports generally flow upward in the hierarchy. The ATEC system will provide computer assistance in report preparation. Sector and nodal control will have the capability to display up to twenty-five different report formats to the technical controller. It will include the capability for both machine and controller entry of address information and data items to the report formats. The capability to

make hard copy of completed reports plus the capability to automatically transmit the reports will also be provided.

Each NCS will provide the capability to store selected report formats needed to satisfy Military Department and DCA reporting requirements, automatically enter into the formats those data items provided by the MAS elements, and display the formats to the Nodal Controller upon request. The Nodal Controller will be provided with the capability to complete those format entries which have not been automatically entered. The capability to make a hard copy of the completed report and transmit the report will also be provided.

SECTION 5

CPMAS ALTERNATIVES

This section addresses the problems of selecting recommended approaches for performance assessment, trend analysis, fault detection/isolation, and telemetry.

Section 5.1 discusses performance assessment alternatives. These alternatives are evaluated and compared to arrive at a recommended CPMAS performance assessment approach. A fault analysis study was conducted to determine equipment failure modes and failure rates.

Section 5.2 discusses CPMAS trend analysis alternatives. Presented are the benefits to be derived from trend analysis. Trend analysis parameters are analyzed and compared for their trend analysis attributes. Techniques that can perform the CPMAS trend analysis function are presented. These techniques are comparatively evaluated. A recommended CPMAS trend analysis approach is derived and consists of parameters to be trended and a trending technique.

Section 5.3 discusses the CPMAS fault detection/isolation function. Alternative fault detection/isolation approaches are discussed and a recommended approach described. Functional flow charts for the recommended approach are documented. Examples are presented to illustrate the fault analysis concept.

The CPMAS telemetry function is described in Section 5.4. Telemetry trade-offs are discussed and recommendations for data formats and telemetry rates are presented.

5.1 Performance Assessment Alternatives

The present discussion is concerned with the performance assessment technical control function. Some of the benefits to be derived from performance assessment are: system performance measure; aid in fault detection/isolation; aid in providing indications of future system degradation; and aid to the technical controller in increasing system margin by proper maintenance scheduling. A performance assessment algorithm must be evaluated in light of these benefits.

5.1.1 Equipment Failure Analysis

An equipment failure analysis was performed in order to assess the usefulness of measuring a particular parameter and to evaluate performance assessment techniques. This analysis consisted of two investigations: a fault cause/effect investigation and a failure rate investigation. The fault cause/effect investigation purpose was to determine which faults occur in the multiplexer, radio, and propagation media; what symptoms these faults would have; and what performance related parameters would be affected. The failure rate investigation purpose was to provide a quantitative estimate of the failure rates of the various modules of the DRAMA radio. These failure rates can then be used to assess the benefits of measuring digital transmission system parameters.

Prior to discussing the results of the equipment failure analysis, some parameters of interest in assessing digital transmission systems will be presented. As discussed in Section 4.1, DCS availability and performance requirements are expressed in terms of four parameters: bit error rate (BER), bit count integrity (BCI), error free seconds/blocks (EFS/B), and jitter. The BER of a transmission system is expressed as the ratio of the number of bits incorrectly detected relative to the total number of bits transmitted. Bit count integrity is the condition that exists when transmitted bits separated by N bits are processed at the receiver separated by N bits. Error free seconds/

blocks is simply the fraction of seconds or data blocks in which no data errors are made. Jitter is the random time modulation that is superimposed upon the data signal.

System level parameters are also indicative of the performance of a digital transmission system, among these are: intersymbol interference, signal-to-noise ratio (SNR), signal-to-distortion ratio (SDR), and carrier-to-noise ratio.

In high bits per second per hertz digital systems, the high data packing results in adjacent pulses spilling into the interval of the data bit being detected, this spilling is called intersymbol interference. In addition to intersymbol interference being present in high bits per second per hertz digital transmission systems, equipment and propagation media degradations can also produce intersymbol interference in the baseband signal.

Signal-to-noise ratio relates the signal power in the baseband to the noise power. SNR would reflect signal attenuation and noise enhancement degradations. Signal-to-distortion ratio is a gross performance measure relating the signal energy present in the baseband to the distortion energy present. The distortion can be manifested as intersymbol interference, delay distortion, intermodulation distortion, co-channel interference, etc. Carrier-to-noise ratio relates the carrier power to the receiver noise power and is closely related to received signal level and signal-to-noise ratio.

Measurement of transmission equipment signals can also be used to assess the digital transmission system. Among these signals are: received signal level (RSL), transmitter signal power (TSP), and transmitter frequency drift (TFD). RSL denotes the power of the received signal, TSP denotes the RF power output of the transmitter, and TFD represents the deviation of the average transmit frequency.

In addition to system level and equipment level parameters, parameters associated with cabling and waveguides are also of interest. Mismatch of impedance between the antenna and the

transmitter results in only a fraction of the signal being radiated. Measurement of VSWR would be indicative of this problem.

In order to assess the usefulness of measuring a particular parameter and to evaluate performance assessment techniques, a fault cause/effect investigation was undertaken. The purpose of the investigation was to determine what faults occur in the multiplexers, radios, and propagation media; what symptoms these faults would have; and which performance related parameters would be affected. Tables 5-1 to 5-4 present the results of this investigation. In these tables the relative sensitivity of the parameters to the various faults are indicated, with (1) being the most sensitive and (2) being the least sensitive.

Table 5-1 presents the results of the fault cause/effect investigation performed upon the radio transmitter. Many of the radio transmitter faults produce distortion which is manifested in digital systems as intersymbol interference. Further degradation of these faults would eventually result in bit errors and a corresponding reduction in error free seconds. Other faults result in signal reduction or noise enhancement. These failures will be indicated by TSP or VSWR in the transmitter and by CNR, SNR or RSL in the receiver. Similarly, increased degradation of these faults would result in bit errors and reduction of error free seconds.

Table 5-2 shows the results of the fault cause/effect investigation that was performed for the radio receiver. In addition to failures producing distortion and signal reduction or noise enhancement, timing recovery circuit failures produce jitter and diversity switch hits result in bit errors in the output mission bit stream.

Table 5-3 shows the results of the fault cause/effect investigation that was performed for the second level multiplexer. This analysis reflects the digital nature of the multiplexer which results in faults causing bit errors or jitter. Status

TABLE 5-1. RADIO TRANSMITTER INDUCED DEGRADATIONS

FAULT	SYMPTOMS	RELATED PERFORMANCE PARAMETERS
CHANGES IN SOLID STATE RF/IF FILTERING CIRCUITS	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
ECHOES IN TWT/ANTENNA LINE	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI, VSWR 2) BER, EFS
TRANSMITTER/ANTENNA MISMATCH	RADIATED SIGNAL REDUCTION	1) VSWR 2) SNR, RSL, CNR 3) BER, EFS
LOCAL OSCILLATOR DRIFT	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
FAULTY TWT	AM/PM CONVERSION	1) ISI 2) BER, EFS
RFI PICK-UP	NOISY TRANSMITTED SIGNAL	1) SNR, CNR 2) BER, EFS
REDUCED AMP GAINS	TRANSMITTER SIGNAL REDUCTION	1) TSP 2) RSL, CNR 3) SNR, BER, EFS
POOR CONNECTIONS	TRANSMITTER SIGNAL REDUCTION	1) TSP 2) RSL, CNR 3) SNR, BER, EFS
MODULATOR DEGRADATION	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
POWER SUPPLY FAILURE	LOSS OF POWER	1) STATUS ALARM

TABLE 5-2. RADIO RECEIVER INDUCED DEGRADATIONS

FAULT	SYMPTOMS	RELATED PERFORMANCE PARAMETERS
CHANGES IN SOLID STATE RF/IF FILTERING CIRCUITS	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
RF PREAMP DEGRADATION	INCREASED RECEIVER NOISE	1) SNR, CNR 2) BER, EFS
REDUCED AMP GAINS	REDUCED SIGNAL LEVEL	1) SNR 2) BER, EFS
POOR CONNECTIONS	REDUCED SIGNAL LEVEL	1) SNR 2) BER, EFS
TIMING RECOVERY CIRCUIT REDUCTION	SAMPLING TIME INACCURACIES	1) JITTER 2) BER, EFS
RFI PICK-UP (FAULTY SHIELDING)	INCREASED RECEIVER NOISE	1) SNR 2) BER, EFS
LOCAL OSCILLATOR DRIFT	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
DEMODULATOR DEGRADATION	EXCESSIVE DISTORTION AT RECEIVER BB	1) ISI 2) BER, EFS
DIVERSITY SWITCH HITS	LOSS OF DATA	1) MUX FER 2) BCI
POWER SUPPLY FAILURE	LOSS OF POWER	1) STATUS ALARM

TABLE 5-3. MUX-DEMUX INDUCED DEGRADATIONS

FAULT	SYMPTOMS	RELATED PERFORMANCE PARAMETERS
TIMING SOURCE OUT OF TOLERANCE	FRAMING AND SYNCHRONIZATION CIRCUITS PRODUCE ERRORS OR FAIL, EXCESSIVE JITTER	1) JITTER 2) BER
FRAME GENERATOR CIRCUITS NOT FRAMING CORRECTLY	ERROR BURSTS CAUSE DECREASE IN MEAN TIME TO LOSS OF FRAME	1) FRAME ERRORS 2) LOSS OF FRAME
BIT STUFF/DESTUFF CIRCUITS DEGRADATION	LOSS OF BIT COUNT INTEGRITY, EXCESSIVE JITTER	1) JITTER 2) BCI
MISTUNED LINE INTERFACE AMPLIFIERS AND IMPEDANCE MATCHING CRTS	LOSS OF PORT	1) STATUS ALARM
RFI PROTECTION FAULTY	ERROR BURSTS	1) BER, EFS
FRAME PATTERN DETECTOR NOT OPERATING PROPERLY	LOSS OF SYNCH LEADING TO HIGH ERROR RATE AND LOSS OF LINK	1) FRAME ERRORS 2) BER, LOSS OF FRAME
POWER SUPPLY FAULTS	LOSS OF DATA, POSSIBLE LOSS OF DIGROUP	1) STATUS ALARM
POOR CONNECTIONS	LOSS OF DATA, POSSIBLE LOSS OF DIGROUP	1) BER, EFS

TABLE 5-4. PROPAGATION MEDIA INDUCED DEGRADATIONS

FAULT	SYMPTOMS AT RECEIVER	RELATED PERFORMANCE PARAMETERS
INTERFERENCE	INCREASED NOISE AT RF/IF/BB	1) SNR, CNR 2) BER, EFS
MULTIPATH-FLAT FADING	RF SIGNAL ATTENUATION, INCREASED BB NOISE, SLOW FADING	1) RSL, CNR 2) SNR 3) BER, EFS
MULTIPATH-FREQUENCY SELECTIVE FADING	RF SIGNAL ATTENUATION, INCREASED BB NOISE, SIGNAL DISTORTION, FAST FADING, DELAY DISTORTION	1) RSL, ISI, CNR 2) SNR 3) BER, EFS
RAIN	RF SIGNAL ATTENUATION, INCREASED BB NOISE, CROSS-POLARIZATION DISTORTION	1) XPD 2) SNR, RSL, CNK 3) BER, EFS
ANTENNA MISALIGNMENT	RF SIGNAL ATTENUATION, INCREASED BB NOISE	1) RSL, CNR 2) SNR 3) BER, EFS
ANTENNA CROSS-POLARIZATION SPILLOVER	CROSS-POLARIZATION DISTORTION	1) XPD 2) BER, EFS
INSUFFICIENT CLEARANCE	RF SIGNAL ATTENUATION, INCREASED BB NOISE	1) RSL 2) SNR 3) BER, EFS

alarms detect loss of data or frame.

The fault cause/effect results for the propagation media are shown in Table 5-4. Multipath fading is one of the dominant failure causes in the 4 to 8 GHz band for line-of-sight (LOS) channels. Frequency or space diversity can substantially reduce these outages. Most LOS fading data is for links in the 10 to 50 mile range. Since the DCS contains LOS links of 80 to 100 miles, special attention must be given to these links. For these long links insufficient clearance and changes in the amount of refraction in the microwave beam may prohibit the transmitted signal from reaching the far antenna.

For systems employing cross-polarized signaling, rain can introduce a rotation in the signal and produce cross-polarization distortion (XPD) in the received signals. Presently, it does not appear that cross-polarized signaling will be required to obtain the data packing desired for DCS transmission and, thus, XPD was not considered as a parameter of interest to assess the digital DCS.

Interference is a potential problem in LOS systems. For the purposes of this study, interference was assumed to manifest itself as noise in the receiver. The problem of interference being intentionally (jamming) introduced into the DCS and potential methods for combating this interference are beyond the scope of this contract and have been recommended as a future research and development area (see Section 10).

The failure rate investigation estimated the failure rates of the various DRAMA radio modules. The DRAMA radio model is presented in Appendix A and shown in Figure 5-1. Using failure rates for the digital applique unit (DAU) ("Microwave Data Transmission Test Program Digital Applique Unit", RADC-TR-76-268) and the MDTS ("Reliability Mathematical Model Megabit Digital Troposcatter System", contract number DAAB07-74-C-0040) as a basis, the failure rates of Table 5-5 were estimated for the DRAMA radio. The DAU and MDTS failure analyses were used for

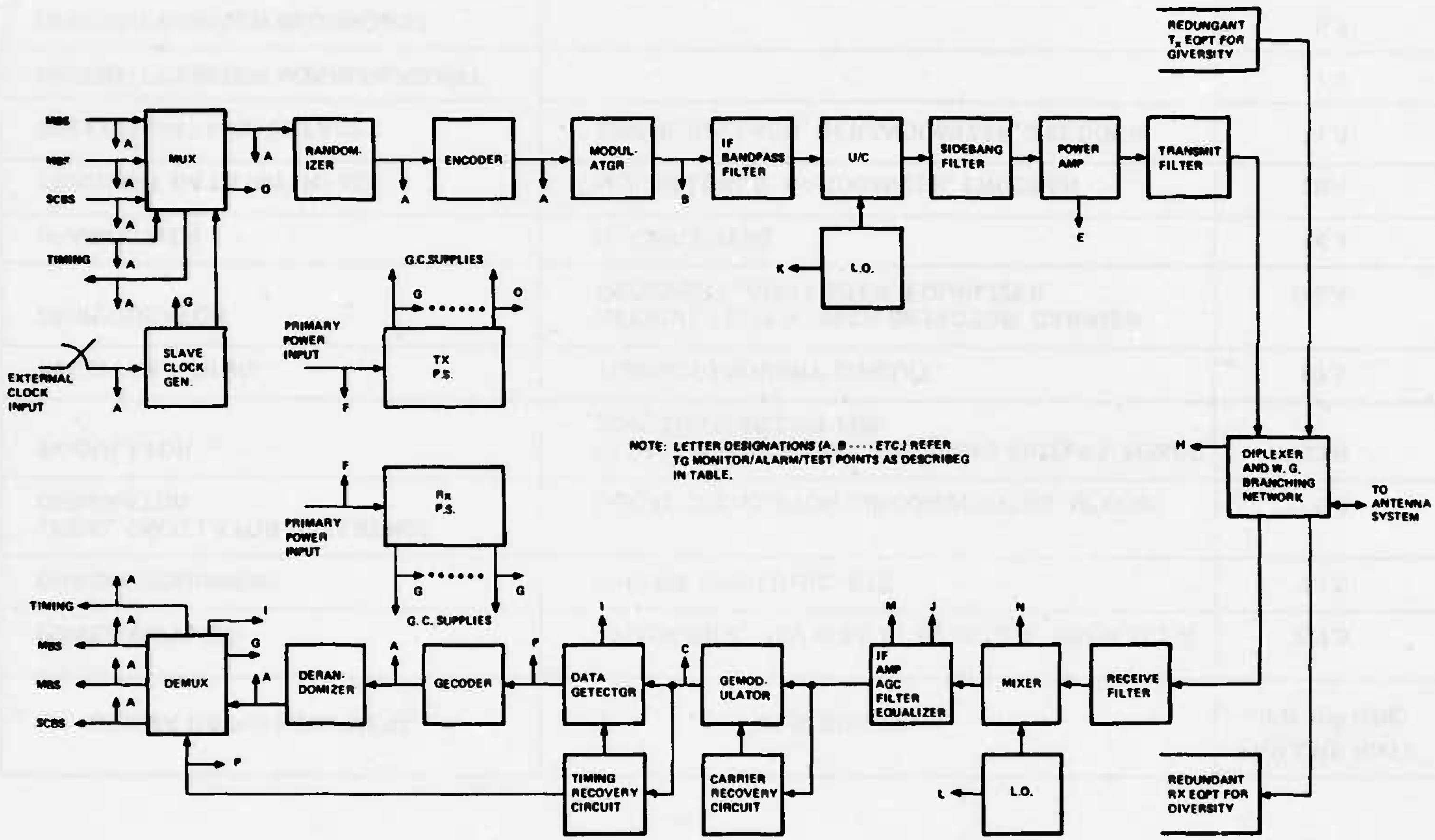


FIGURE 5-1. DRAMA RADIO FUNCTIONAL BLOCK DIAGRAM

TABLE 5-5. DRAMA RADIO FAILURE INVESTIGATION RESULTS

DRAMA RADIO EQUIPMENT	DESCRIPTION	FAILURE RATE (PER 10^6 HRS)
POWER SUPPLIES	+15V @ 3.6 A; -15V @ 4.8 A, -5V @ 1.2 A, +5V @ 31.2 A	207.0
CHASSIS EQUIPMENT	WIRING, SHIELDING, ETC.	81.0
LOCAL OSCILLATOR REFERENCE GENERATOR	*LOCAL OSCILLATOR, UP CONVERTERS, MIXERS*	5.3
MODULATOR	IF BANDPASS FILTERS, SIDEBAND FILTERS, POWER AMP, TRANSMIT FILTER	33.0
RECEIVER TIMING	TIMING RECOVERY CIRCUIT	97.5
DEMODULATOR	RECEIVE FILTER, DATA DETECTOR, CARRIER RECOVERY, AGC FILTER, EQUALIZER	140.4
IF AMPLIFIER	IF AMPLIFIERS	14.2
TRANSMIT DATA INTERFACE	MULTIPLEXER, RANDOMIZER, ENCODER	15.1
RECEIVE DATA INTERFACE	DEMULTIPLEXER, DERANDOMIZER, DECODER	11.0
DIVERSITY SWITCH NONREDUNDANT		7.0
DIVERSITY SWITCH REDUNDANT		6.9
TOTAL		618.4

this failure rate investigation because of their data rate and power output similarities to the DRAMA radio. The failure rates shown in this table are for a dual diversity radio configuration.

The dominant failure modes are: power supply failures, demodulator failures, and receive timing generation failures. The system failure rate of Table 5-5 corresponds to a MTBF of 1617 hours, whereas the specified MTBF for the DRAMA radio is 1600 hours.

5.1.2 Description of Techniques

Five generic performance assessment techniques for digital transmission systems will be discussed below. They are: error counters, eye opening monitor, pseudo error counters, channel estimation, and jitter monitor. A set of performance assessment techniques will be chosen to perform the wideband digital measurement function (WDMF) of Figure 4-5 of Section 4. The performance assessment CPMAS function would be performed by the WDMF, by the examination of equipment alarms, by counting frame error pulses, and by thresholding/processing equipment analog parameters.

5.1.2.1 Error Counter Techniques

Perhaps the simplest conceptual method of assessing performance involves counting errors. One error counting technique performs a bit-by-bit comparison of the detected data sequence with the transmitted data sequence and counts the number of errors to determine bit error rate (BER) and error free seconds (EFS). Since the transmitted data sequence must be known at the receiver, data transmission must be interrupted.

In addition to transmitting a known data sequence, code word parity bits, format violations, or frame errors can be used as an error counter without interrupting data transmission. A code word parity approach has been proposed for assessing digital transmission performance. This approach increases the T1 frame by adding a frame parity bit. Odd number of errors in the block

can then be detected. Application of this technique to the digital DCS is complicated by the need to increase the frame length by adding the parity bit and by problems resulting from bulk encryption.

When partial response modulation is used, data errors can be detected by monitoring format violations in the three-level partial response signal. Minor error propagation effects arise, which result in an ambiguity in measuring error rate. This ambiguity is normally less than a factor of four. For the no intersymbol interference case, an ambiguity of about four-thirds results. Counting format violations would provide excellent measurements of bit error rate and error free seconds.

Framing bits in the radio and MUXs can be monitored for errors. Framing errors can be related to bit error rate. Since the bit error rate is related to the number and performance of the links traversed, the frame error rate in the radio, second level MUX, and first level MUX will differ. For a regenerative system the radio frame error rate is related to the link error rate, the second level MUX frame error rate is related to the bit error rate between T1 breakouts, and the first level MUX frame error rate is related to route error rates.

The main advantage of the error counter technique is that it directly measures error rate and, as such, does not require any additional extrapolations or calculations. Error counter performance assessment techniques have the disadvantage of requiring long processing time to obtain a statistically significant number of errors when the error rate is low. For example, about 10^{10} data bits are required to estimate a BER of 10^{-8} with 10% accuracy (one standard deviation). At present data rates being considered for the DCS, it would take an exceedingly long time to count errors and would not provide an advanced indication of a degradation.

5.1.2.2 Eye Opening Monitor

Using the baseband signal to trigger an oscilloscope generates what has been called an eye pattern. The eye pattern is one of the oldest means of assessing performance of a PAM system. Although there is much information contained in the eye pattern, extraction of this information in a format that can be applied by the technical controller remains to be determined. Since just about every performance assessment technique can be related in some manner to an eye pattern parameter, only eye opening will be considered in this section.

As intersymbol interference and noise increase, the eye pattern becomes fuzzier and the eye opening decreases. By monitoring this eye opening, the technical controller has an indication of noise immunity. It can be shown that the eye opening can be used to upper bound the BER. Although this bound may be useful, it is not always tight and it is possible to have acceptable performance for very small eye openings. The reason for this is that the eye opening is related to the worst intersymbol interference pattern, which may not be very representative of the average effect of the intersymbol interference.

Since most common system degradations (e.g., noise, intersymbol interference producing degradations, modulation/demodulation nonlinearities, etc.) result in a reduction in the eye opening, the advantage of eye pattern technique is that small system degradations can be detected and used to provide the technical controller with an early indication of degradation.

An eye opening monitor was developed and tested as a means of assessing performance of a high-speed digital system. Additive disturbances and carrier frequency offset degradations were inserted to test the eye opening monitor. The results of these tests are: (1) that for different degradation sources the accuracy of the monitor varied and (2) that small degradations can be detected and used to provide an early warning capability.

5.1.2.3 Pseudo Error Counters

Due to the processing time required to count actual data errors, Gooding[1], while at GTE Sylvania, proposed a performance assessment technique that artificially amplifies the error rate by using a series of degraded detectors. The output sequences can be used to form an error rate estimate for each of the degraded detectors (called pseudo error rates). These pseudo error rates are used to extrapolate to the actual error rate by using information concerning the form and extent of the degraded detectors. Figure 5-2 shows how the pseudo error counter technique can be applied.

The detector degradation proposed by Gooding was to modify the threshold level in the detector. The use of a modified threshold level was shown to be fairly robust with respect to the form of degradation for several baseband modulation schemes. However, Gooding was primarily concerned with fading channels and was trying to estimate average BER (averaged over both noise and channel fluctuations). Therefore, although the pseudo error rate technique can be used for LOS links in which a short-term bit error rate estimate is desired, the theoretical analysis by Gooding does not apply. Potential methods of extrapolating the BER estimate from the pseudo error rates have been proposed and compared.

The attractiveness of the pseudo error technique is due to several factors. Firstly, pseudo error rate is a monotone function of BER and larger than the latter by several to many orders of magnitude. Thus pseudo errors can be used as a precursive indicator of system degradation. Secondly, pseudo error counters do not require knowledge of the transmitted data. Lastly, BER can be estimated from knowledge of the pseudo

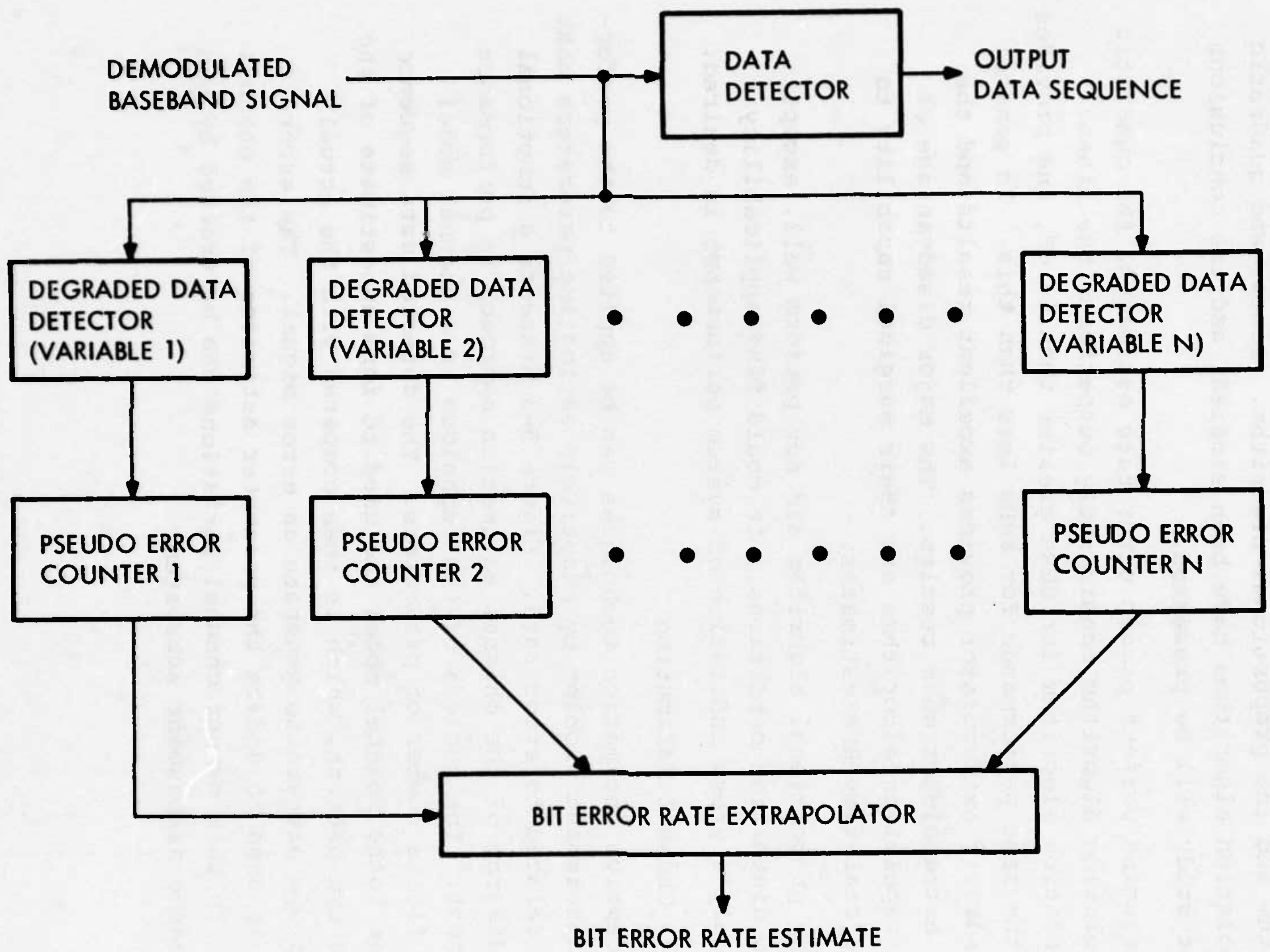


FIGURE 5-2. PSEUDO ERROR COUNTER PERFORMANCE ASSESSMENT TECHNIQUE

errors. The methodology of relating pseudo errors to BER can be divided into two generic categories, the extrapolation algorithm and the proportional algorithm. Linear and quadratic extrapolation algorithms have been studied[2] and the conclusions of that study will be presented.

Assuming perfect pseudo error rate estimates, the quadratic extrapolation algorithm considerably outperforms the linear extrapolation algorithm for SNRs greater than 14 dB, and provides about the same performance for SNRs less than this. In general the quadratic extrapolator provides excellent results and the linear extrapolator good results. The major disadvantage of the extrapolation algorithms are their marginal capability to provide real-time BER estimates.

The proportional algorithm did not perform well, except for low distortion conditions. It could find applicability where only a gross indication of system performance is desired.

5.1.2.4 Channel Estimation

Adaptive estimation techniques can be applied to the performance assessment problem by adaptively estimating parameters that can be related to error rate. Figure 5-3 presents a functional block diagram of the channel estimation approach to performance assessment. The nucleus of the technique is a channel model with a finite number of parameters. The detected data sequence is input tothe channel model and used to form an estimate of the sampled eye pattern, which is then compared with the actual sampled eye pattern to generate an error signal. The error signal is used to update the parameter estimates of the channel model. In this manner channel variations can be tracked by the performance assessment subsystem.

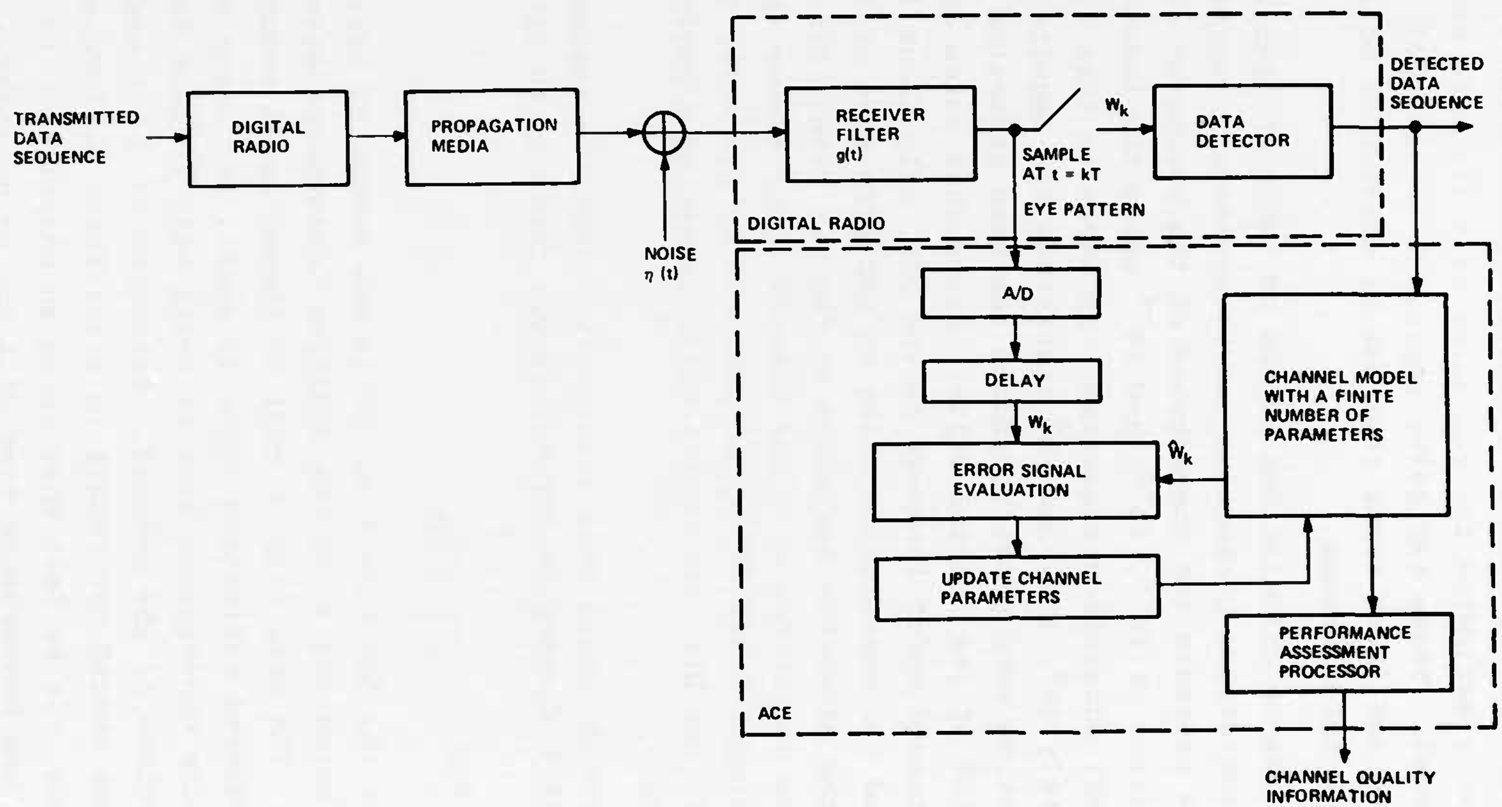


FIGURE 5-3. COMMUNICATIONS SYSTEM WITH CHANNEL ESTIMATION

A channel estimator (CE) was analyzed as a means of assessing the performance of a digital transmission system. CE adaptively estimates the tap gains of a discrete nonlinear channel model. These tap gains represent intersymbol interference and nonlinear terms that can be considered nonlinear intersymbol interference.

Performance calculations of the CE indicate that intersymbol interference parameters can be accurately estimated. Figure 5-4 presents the convergence of the parameter estimates for step sizes of 10^{-2}, 10^{-3}, and 10^{-4} using the Least Mean Square (LMS) adaptation algorithm. As shown in this figure approximately 10^2, 10^3, and 10^4 iterations are required by the respective step sizes to reduce the mean parameter estimation error to 10% of its initial value. Since data rates of about 10^7 bits per second are of interest in the DCS, only about 1 ms would be required for convergence using an LMS step size of 10^{-4} and updating the parameter estimates at the bit rate. Since significant time variations of a LOS channel occur slower than 1 ms, hardware simplifications can be achieved by iterating the CE slower than the bit rate, while still retaining a performance safety margin.

The steady state mean square error (MSE) in estimating the intersymbol interference parameters was found to be given by

$$\mathrm{MSE} = \frac{2\sigma^2}{1 - \Delta\,\mathrm{Np}} \tag{5-1}$$

where Δ is the LMS step size, Np is the number of parameters to be estimated and σ is the additive disturbance standard deviation. The step size Δ must be chosen small enough that the mean squared estimation error is small, but large enough such that the convergence time is small with respect to the time variations of the channel. Selection of Δ to meet these restrictions should not result in significant performance degradations. It is felt that using an adaptive Δ to reduce both error and convergence time will not be necessary.

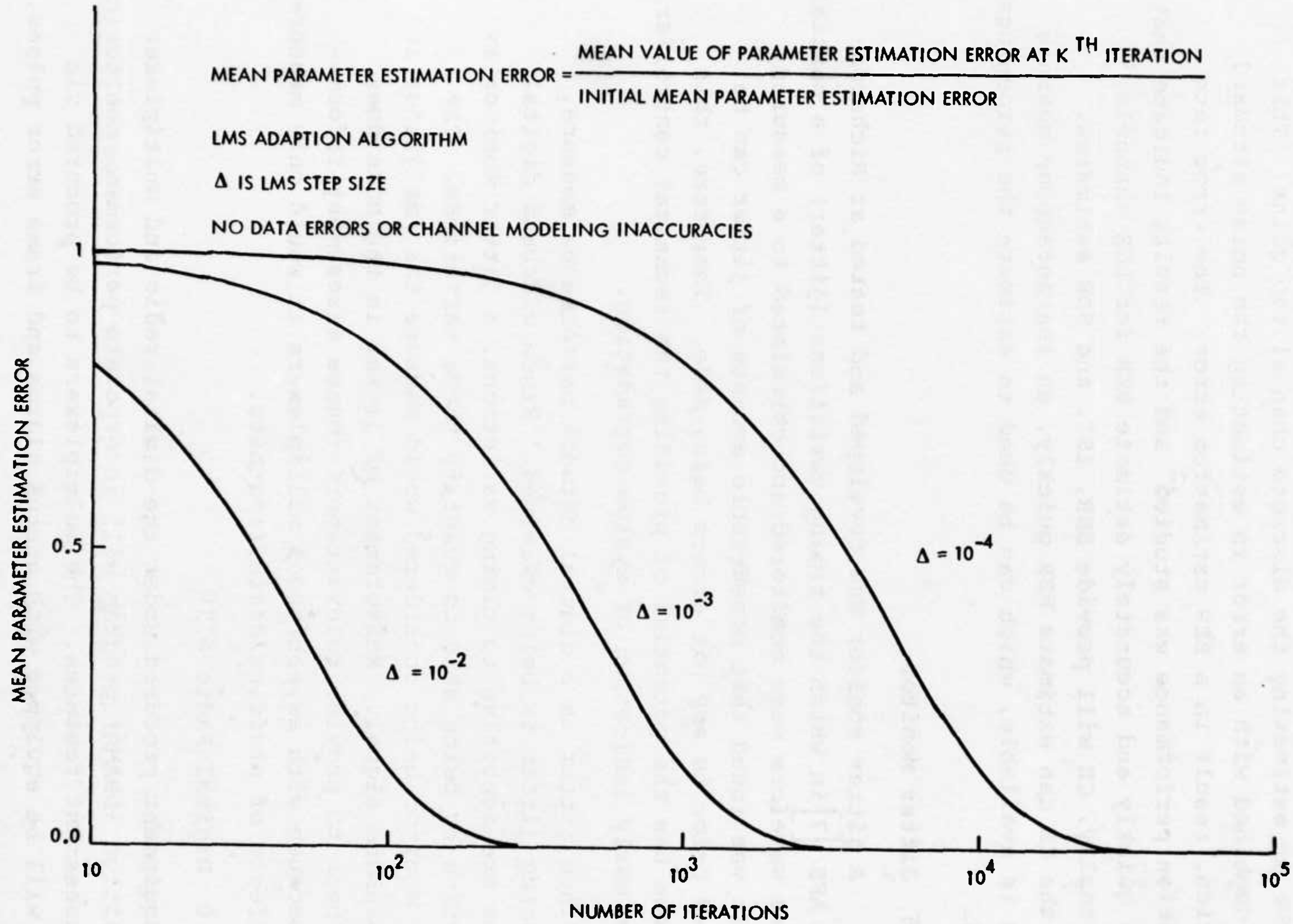


FIGURE 5-4. MEAN PARAMETER ESTIMATION ERROR CONVERGENCE

The effect of noise on the channel estimator is to produce an error in estimating the discrete channel tap gains. This error combined with an error in estimating the noise standard deviation, result in a BER estimation error. The error rate estimation performance was studied[2] and the results indicate that CE can quickly and accurately estimate BER for LOS channels. Additionally, CE will provide SNR, ISI, and SDR estimates. Since the CE can estimate BER quickly, an instantaneous measure of BER is available, which can be used to estimate the percentage of EFS.

5.1.2.5 Jitter Monitor

A jitter monitor was developed and tested at Richards-Gebaur AFB [7] in which the timing variations (jitter) of a partial response waveform were monitored and correlated to a measured BER. It was found that measureable amounts of jitter can be recorded prior to any bit errors being made. Therefore, this technique has the potential of providing the technical controller with an early indication of system degradation.

Since jitter is a digital network performance measure, monitoring jitter is being examined. Since wideband digital systems are sensitive to timing variations, a jitter monitor is attractive by being able to quantify these variations. The jitter monitor being considered would measure the rms jitter in the baseband signal. Measurement of jitter in the MUXs does not appear to provide relevant performance assessment information because with asynchronous multiplexers it would only measure the effects of stuffing/destuffing bits.

5.1.2.6 Digital Radio BITE

Equipment procured under the digital radio and multiplexer acquisition (DRAMA) program will incorporate performance monitoring and assessment features. The multiplexers to be procured via DRAMA will be equipped with status alarms and frame error pulses,

while the digital radio will be equipped with assessment parameters in addition to frame error pulses and status alarms. The performance monitoring features of the DRAMA equipment are discussed in detail in Appendix A.

The DRAMA radio assessment parameters can be used in lieu of or in addition to the performance assessment techniques presented above.

5.1.3 Performance Assessment Technique Comparison

In this section the performance assessment alternatives presented in the previous section will be compared. This comparison will be used in Section 5.1.4 to define a recommended CPMAS performance assessment technique.

Table 5-6 shows the performance assessment techniques and the criteria that will be used to select a recommended performance assessment technique or set of techniques. The five selection criteria are specifications measured, trend analysis parameters, BER estimation accuracy, speed of assessment, and cost. Specifications measured reflects the number of DCS performance requirements parameters that can be measured by each technique. The performance requirements parameters of the DCS are given in Table 4-1. Trend analysis parameters selection criteria indicate the ability of each technique to provide parameters recommended as possible trending parameters. BER accuracy relates to the ability of each technique to accurately estimate BER. Speed of assessment reflects the time required by each technique to assess performance. The non-recurring production costs of each technique is reflected in the cost criterion.

In Table 5-6 each criterion is assigned a weight as to its relative importance in selecting a performance assessment technique. The weights are either two (2) indicating a criteria of greater importance or one (1) indicating lesser importance. As shown in Section 4 trend analysis can increase system availability and, thus, the ability of the techniques to measure parameters to be trended is of greater importance and is given a two weight.

TABLE 5-6. DIGITAL RADIO PERFORMANCE ASSESSMENT TECHNIQUE SELECTION

CRITERIA (WEIGHTS) / TECHNIQUE	SPECIFICATIONS MEASURED (1)	TREND ANALYSIS PARAMETERS (2)	BER ESTIMATION ACCURACY (2)	SPEED OF ASSESSMENT (1)	COST (1)	FIGURE OF MERIT
ERROR COUNTER *	0/10 *	0	0/10 *	0/2 *	0/9 *	0/41 *
PSEUDO ERROR COUNTER	10	0	6	5	6	33
EYE OPENING	5	0	4	10	6	29
CHANNEL ESTIMATION	10	6	8	10	5	53
JITTER MONITOR	5	0	0	10	6	21
DRAMA BITE	5	6	2	10	9	40

* FORMAT VIOLATIONS WOULD ONLY BE USED WITH PARTIAL RESPONSE

Estimation of BER can be used to detect unalarmed radio failures which will increase system availability. The more accurate these estimates are, the better the ability to detect unalarmed radio failure. Therefore, a weight of two is assigned to BER estimation accuracy. The three other criteria, although important in selecting a performance assessment technique, are of lesser importance than the previously discussed criteria. These three criteria will not directly increase system availability and are therefore given a weight of one.

The performance assessment techniques are given a rating from zero to ten for their ability to satisfy each criterion, with ten being the best rating. These ratings are then multiplied by the criteria weights and summed to give a figure of merit for each technique. This figure of merit will be used to recommend a performance assessment CPMAS subsystem in Section 5.1.4.

The following discussion will present the rational for the criteria ratings of Table 5-6. The specifications parameters and the trend analysis parameters that the various performance assessment techniques measure are shown in Table 5-7. As shown in this table the greatest number of specifications measured by any single technique is two. Therefore, those techniques that measured two specification parameters were given a criteria rating of ten and those measuring one were given a criteria rating of five.

It is shown in Section 5.2.3 that the two best parameters to be trended are transmitted signal power and signal-to-distortion ratio. The third parameter recommended for trending is signal-to-noise ratio. The criteria ratings of Table 5-6 for trend analysis parameters were arrived at by assigning a rating of four if a technique measured either transmitted signal power or signal-to-distortion ratio and a rating of two for measuring signal-to-noise ratio.

TABLE 5-7. PERFORMANCE ASSESSMENT PARAMETERS

PARAMETERS / TECHNIQUES	SPECIFICATIONS MEASURED				TREND, ANALYSIS PARAMETERS		
	BIT COUNT INTEGRITY	ERROR FREE SECONDS/ BLOCKS	JITTER	BIT ERROR RATE	TRANSMITTED SIGNAL POWER	SIGNAL-TO-DISTORTION RATIO	SIGNAL-TO-NOISE RATIO
ERROR COUNTER (FORMAT VIOLATION)		×		×			
PSEUDO ERROR COUNTER		×		×			
EYE OPENING				×			
CHANNEL ESTIMATION		×		×		×	×
JITTER MONITOR			×				
DRAMA BITE				×	×		×

The accuracy of a performance assessment technique to estimate bit error rate is dependent upon the causes of the bit errors and the bit error rate being estimated. An example of the BER estimation accuracy expected from the various performance assessment techniques is shown in Figure 5-5. This example is for baseband to baseband channel with a moderate amount of intersymbol interference (two terms of amplitude 0.1 compared to a signal term of amplitude 1.0). The DRAMA curve in this figure assumes that signal-to-noise ratio is used to estimate BER. The eye opening monitor measures the eye opening (0.8 for this example), estimates the noise present, and then estimates BER. A perfect noise estimate was assumed for this example. The BER estimation accuracy of the pseudo error counter and channel estimation are discussed elsewhere[2] and will not be elaborated on further except to note that the pseudo error counter used a proportional extrapolation technique to estimate BER. Format violations will correlate directly with bit errors and will provide a very accurate measure of BER. In Table 5-6 a criteria rating of ten was assigned to format violations. The four techniques of Figure 5-5 were ranked as to their BER estimation accuracy and the criteria rating decremented by two for each subsequent ranking position. The eye opening technique was lowered by one ranking position to account for the degradation in estimating BER with a nonperfect noise estimate. The jitter monitor does not estimate BER and was given a criteria rating of zero.

Format violations count errors and under low error rate conditions will require an extremely long time to assess performance. Therefore, a low criteria rating of two was assigned to format violations for the speed of assessment criteria. Pseudo error counters amplify the error rate and reduce to assessment time compared to the format violation approach but may still require long assessment times for low error rates. A criteria rating of five was assigned to the

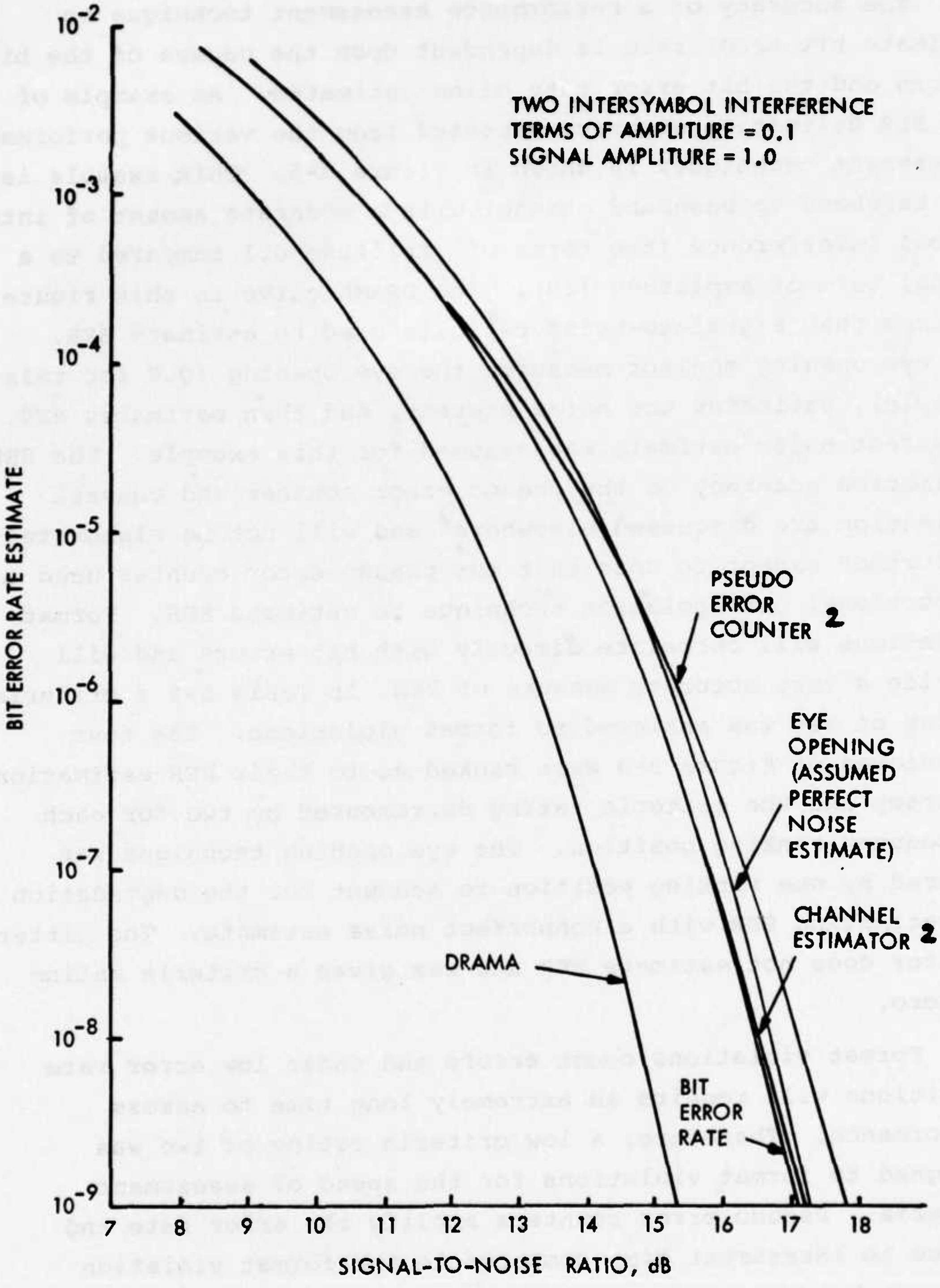


FIGURE 5-5. BIT ERROR RATE ESTIMATION ACCURACY

pseudo error counter measure performance related parameters and should require approximately one second to assess performance. A one-second assessment time is negligible compared to the telemetry channel transmission time and a criteria rating of ten was assigned to each of these techniques.

An estimate of relative costs for each performance assessment technique was used to derive the cost criteria ratings of Table 5-6 by using a linear functional weighting.

It should be reiterated that if partial response is not the modulation technique, then format violations can not be used and a criteria rating of zero results for each criteria.

5.1.4 Recommendations

As shown in Table 5-6 channel estimation is the best single performance assessment technique. A combined approach of channel estimation and DRAMA BITE would have a figure of merit of sixty (increasing the trend analysis parameter rating by four and decreasing the cost rating by one compared to channel estimation). In addition, if format violations is the modulation technique employed, then a combined approach of channel estimation, DRAMA BITE, and format violations would have a figure of merit of sixty-three (increasing the BER estimation accuracy rating by two and decreasing the cost rating by one compared to channel estimation plus DRAMA BITE). It can be easily shown that if partial response is not employed that no combination of techniques can provide a figure of merit greater than sixty and with partial response no combination can provide a figure of merit greater than sixty-three.

In summary, channel estimation is the best single performance assessment technique; channel estimation plus DRAMA BITE is the best combined approach and is more cost effective than channel estimation alone, and for partial response systems, it is recommended that format violations be used in addition to channel estimation and DRAMA BITE.

5.2 Trend Analysis Alternatives

In this section the trend analysis CPMAS function is addressed. The results of an analysis showing the effects of trend analysis upon equipment reliability is presented. It is shown that failure prediction can greatly increase the equipment mean-time-between-failures. Parameters recommended for trending and the parameter selection process are also discussed.

Five techniques for implementing the trend analysis CPMAS function are presented and compared. These techniques are existing approaches applicable to trending parameters of a digital transmission system. The process by which a trend analysis approach was selected is discussed and the trend analysis recommendations presented.

5.2.1 Trend Analysis Benefits

Trend analysis is the CPMAS function responsible for gathering and processing long term statistical data. This information can be used to establish mean-time-between-failures for the various transmission equipment and to recommend maintenance cycles. In addition, trend analysis can predict failures by trending parameters that are indicators of future failures. The primary benefit of trend analysis is failure prediction which can increase the equipment mean-time-between-failures by predicting failures and allowing repair prior to failure occurrence.

In particular, with λ_p and λ_u being, respectively, the total component failure rates for predicted and unpredicted failures, then the equipment MTBF is given by

$$MTBF = \frac{1}{\lambda_u + \lambda_p} \tag{5-2}$$

and the fraction of failures predicted is given by

$$p = \frac{\lambda_p}{\lambda_u + \lambda_p} \tag{5-3}$$

The mean-time-between unpredicted failures with trend analysis (MTBUF) is related to the total component failure rate for unpredicted failures.

Specifically, MTBUF can be expressed as

$$MTBUF = \frac{1}{\lambda_u} = \frac{MTBF}{1-p} \qquad (5\text{-}4)$$

The above analysis models the failure occurrances in the equipment as a compound Poisson process. An alternate means of evaluating the benefits of trend analysis is to model the failure occurrances as a renewal process. Using a renewal process analysis gives

$$MTBUF = \frac{MTBF}{1-p} - pMPT \qquad (5\text{-}5)$$

where MPT is the mean prediction time, that is, the average time for a predicted failure to occur.

Physically, the two analyses can be related to degree of maintenance. That is, whether a failed component or equipment is replaced to effect repair. As equipment repair will be performed by modular replacements, the expected benefits of trend analysis can be approximated by the above results.

As more failures are predicted with a long lead time, then it will result in maintenance personnel making trips to repair equipment prior to failure. It can be shown that the mean-time-between-repairs with trending (MTBR) can be expressed as

$$MTBR=MTBF - MPT \quad 1 + \frac{1-p}{p} \ln(1-p) \qquad (5\text{-}6)$$

Predicting failures when none are imminent (false alarms) would result in a large MPT.

These trend analysis benefits are illustrated in Figure 5-6. An equipment MTBF of 1600 hours was used in this figure. As shown the equipment mean-time-between unpredicted failures can be greatly increased by predicting failures. For example, predicting 20% of the failures results in about a 25% increase in the equipment MTBF while having a negligible effect upon the mean-time-between repairs.

5.2.2 Parameters to be Trended

An analysis of equipment failure modes was conducted and discussed in Section 5.1.1. This analysis produced a list of parameters affected by equipment/media degradations. From this list parameters for trend analysis were selected. The method for selecting parameters is illustrated by Table 5-8. Each parameter was rated from zero to ten (with ten being the

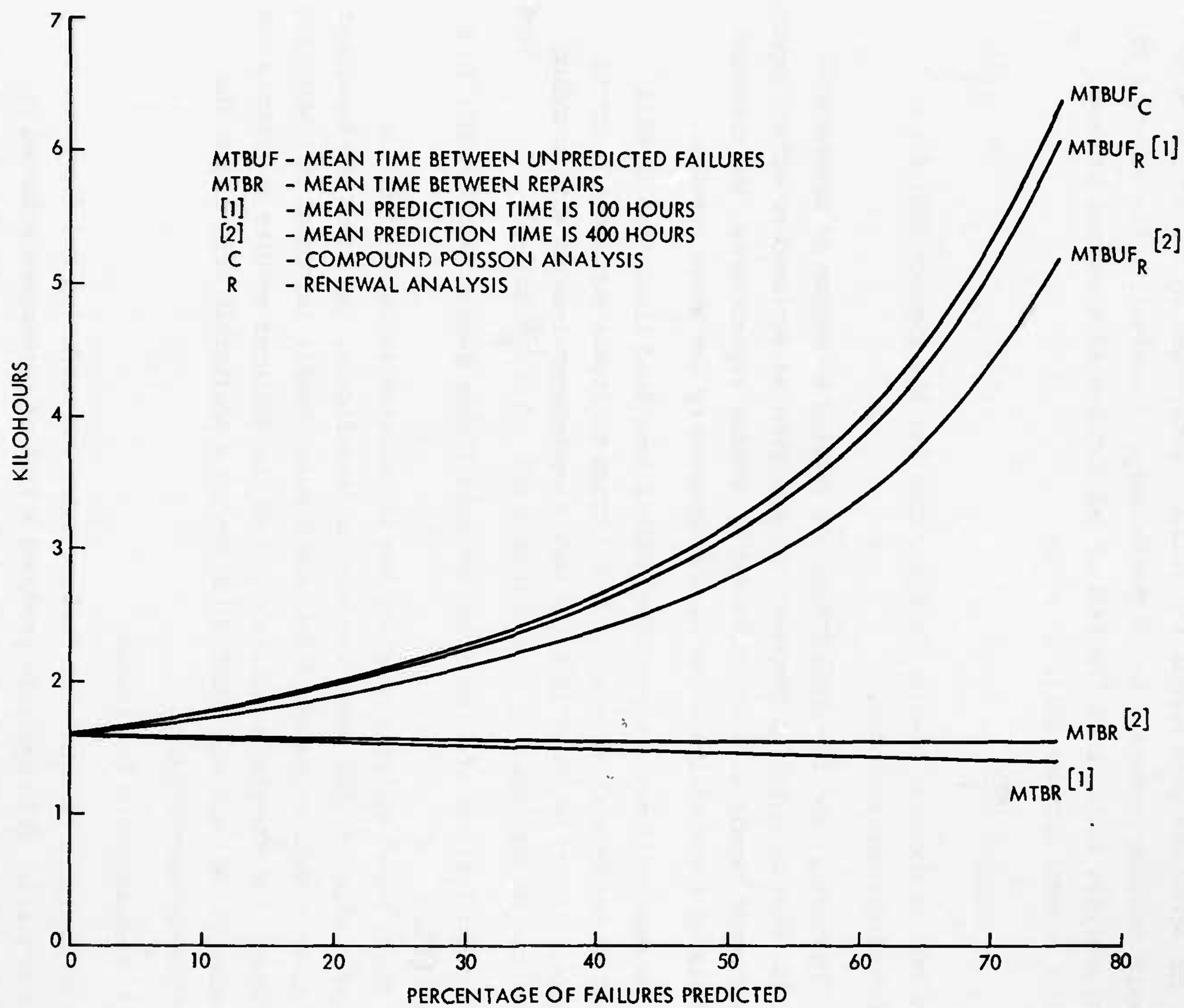


FIGURE 5-6. TREND ANALYSIS BENEFITS

TABLE 5-8. TREND ANALYSIS PARAMETER SELECTION

CRITERIA (WEIGHTS) / PARAMETER	PARAMETER AVAILABILITY (2)	PRECURSOR TO EQUIPMENT FAILURE (2)	TRENDABILITY			RELATIVE NUMBER OF DEGRADATIONS (2)	TOTAL
			INSENSITIVITY TO EXTERNAL PARAMETERS (1)	PARAMETER MEASUREMENT ACCURACY (1)	MODELABILITY (1)		
TRANSMITTED SIGNAL POWER	10	10	10	10	10	3	76
SIGNAL-TO-NOISE RATIO	10	5	7	8	4	5	59
JITTER	3	10	9	5	6	4	54
SIGNAL-TO-DISTORTION RATIO	10	10	9	9	8	7	80
RECEIVED SIGNAL LEVEL	10	4	2	8	4	2	46
TRANSMITTER FREQUENCY DRIFT	6	10	10	7	8	1	59
BIT ERROR RATE	10	2	2	5	2	10	53

best) as to its ability to satisfy each selection criteria, the criteria were weighted as to their relative importance, and a figure of merit for each parameter derived. This figure of merit was used to select parameters to be trended.

The parameter selection criteria are: parameter availability, precursor to equipment failure, insensitivity to external parameters, parameter measurement accuracy, modelability, and relative number of degradations. Parameter availability reflects the accessability of the parameter; that is, is it an equipment output, does it require processing, etc. Precursor to equipment failure reflects the ability of a parameter to indicate with sufficient lead time that an equipment failure is impending.

The next three criteria are indicative of the "goodness" of a parameter as a trending variable. Insensitivity to external parameters means that a parameter can be accurately trended if it is influenced only by equipment variations as opposed to being influenced by external nonequipment related parameters like fading and interference. Parameter measurement accuracy reflects that trending accuracy is related to measurement accuracy. Modelability indicates the ability of a parameter to be modeled by a simple time function. Also to be considered by this criteria is the periodic variations in some parameters that result in poor trending.

The last criteria, relative number of degradations, reflects the number of equipment degradations that a parameter is sensitive to. Each selection criteria was assigned a weight of either one or two. A weight of one was assigned to the three "trendability" criteria. The remaining three criteria were each assigned a weight of two reflecting the relative importance of choosing a parameter that provides a good indication of a large number of equipment failures at low cost. Basically, the weights were assigned to reflect the feeling that parameters should be mainly chosen for their failure predictive attributes and due to the risk involved in trending, a low cost solution is preferred.

The parameter availability ratings of Table 5-8 reflect the availability of each parameter. A rating of ten was assigned to each parameter that is an output from the recommended performance assessment approach, that is,

DRAMA BITE and channel estimation. Transmitter frequency drift was assigned a rating of six since it is available in DRAMA BITE but is not output and thus would require processing. Since the jitter monitor was not a recommended performance assessment technique, the jitter parameter was assigned a rating of three to reflect the high cost of obtaining this parameter. If jitter is an available parameter, then it would be recommended for trending.

Precursor to equipment failure reflects the confidence that one has in relating changes in parameters to future equipment failures. Transmitted signal power and transmitter frequency drift are parameters that indicate transmitter equipment degradations and should provide an excellent indication of impending equipment failures. Also, increased amounts of jitter and signal distortion can be effectively used to indicate future equipment failures. Signal-to-noise ratio, received signal level, and bit error rate, on the other hand, received lower ratings for this criteria since variations in these parameters will occur without indicating impending degradations, due to the statistical nature of these parameters. For example, on line of sight channels it is expected that a period of error free operation can follow periods of degraded performance due to transmission media variations.

The candidate parameters to be trended were rated as to their insensitivity to external parameters. Received signal level (RSL) varies primarily due to signal fading as opposed to equipment degradations. It would be extremely difficult to accurately predict equipment failures by trending RSL due to fading masking to equipment induced degradations. Bit error rate also received a low rating due to it being affected by fading and interference.

Received signal level can be used to remove the fading effects upon signal-to-noise ratio. When this is done a relatively high rating (a rating of seven was assigned) for the insensitivity to external parameters criteria results for SNR. Transmitter frequency drift and transmitted signal power are very insensitive to external parameters being totally independent of media and interference. Frequency selective fading can produce distortion and, thus, effect SDR. However, frequency selective fading on line of-sight links occurs only during deep fades (greater than about 30 dB) and occurs much less frequently than the shallow fading that influences RSL. It is

felt that this frequency selective fading will be so infrequent as to warrant a rating of nine for SDR. The effect of fading and interference upon low frequency jitter is an issue of conjecture. A rating of nine was assigned since a minimal effect is anticipated.

Parameter measurement accuracy is important because prediction accuracy is related to measurement accurancy. Measurement accuracy of BER and SDR were presented in Figure 5-5 and Equation 5-1 and used to determine the criteria rating of Table 5-8. The other ratings are subjective and reflect estimates of accuracy that can be expected for the various parameters. Procurement of the DRAMA radio may provide the additional information required for assessing this criterion.

Since functional models for the time dependent variations of the parameters is not known, the parameter selection process of Table 5-8 modelability indicates the ability of a parameter to be modeled by a low order polynomial. Since slowly varying parameters are better candidates for being modeled by a low order polynomial, the criteria ratings were selected to reflect the expected rate of change of the various parameters.

The ratings for the relative number of degradations reflect the failure analysis of Section 5.1.1 and, in particular, the results of Tables 5-1, 5-2, and 5-5. As shown in Table 5-8, BER responds to the most equipment degradations and transmitter frequency drift responds to the least.

5.2.3 Trend Analysis Methods [3], [4]

The problem of processing parameter measurements to predict future values of that parameter will be addressed in this section. Five generic techniques for predicting future parameter values will be discussed. First, the trend analysis problem will be mathematically formulated.

5.2.3.1 Statement of the Trend Analysis Problem

For trend analysis it is assumed that a set of N observations $\left\{\tilde{X}(t_k)\right\}_{k=1}^{N}$ of a parameter process X(t) are available. The observations are related to the actual parameter values by

$$\tilde{X}(t_k) = X(t_k) + \varepsilon_k \quad ; k=1, \ldots. N \tag{5-7}$$

where ε_k is the parameter measurement error and t_N is the present (most recent) time. The observations are assumed equally spaced. The problem is to process the past and present observations and form an estimate of $X(t)$ at time t_{N+M}. This estimate is denoted $\hat{X}_N(t_{N+M})$, that is, the estimate of $X(t_{N+M})$ made at time t_N. The estimation error is defined as

$$E_N(t_{N+M}) = X(t_{N+M}) - \hat{X}_N(t_{N+M}) \tag{5-8}$$

Minimization of the estimation error with respect to a suitable performance measure is the goal of the trend analysis methods.

5.2.3.2 Linear Regression

Linear regression assumes that the parameter process $X(t)$ is composed of a linear combination of functions. Linear regression evaluates the coefficients that result in the best fit between the observations and the process model. In particular, it is assumed that the parameter process is expressible as

$$X(t_k) = \sum_{n=1}^{K} a_n z_n(t_k) \tag{5-9}$$

where $Z_n(\cdot)$ (n=1, ..., k) are known (assumed) functionals and a_n are the unknown coefficients to be estimated.

As an example, if the parameter process is slowly varying with time then a quadratic polynominal may be a good representation for the parameter process. Therefore, $X(t_k)$ can be written as

$$X(t_k) = a_1 + a_2 t_k + a_3 t_k^{\,2} \tag{5-10}$$

Once the parameter process model of Equation 5-9 has been assumed, the coefficients a_n must be estimated, the estimates of the coefficients at time t_N are denoted by $\hat{a}_n(t_N)$.

The linear regression technique evaluates the coefficients $\hat{a}_n(t_N)$; n=1,..., K, that minimizes the mean square difference between the estimation and observation process. That is, the coefficients $a_n(t_N)$; n=1,..., K, are evaluated such that

$$\sum_{k=N-L+1}^{N} [\hat{X}_N(t_k) - \tilde{X}(t_k)]^2 \tag{5-11}$$

is minimized. The variable L indicates the number of observations over which the linear regression technique will be employed.

Once the coefficients are estimated, the parameter process is forecast at time t_{N+M} using

$$\hat{X}_n(t_{N+M}) = \sum_{n-1}^{K} \hat{a}_n(t_N)\, Z_n(t_{N+M}) \tag{5-12}$$

It can be shown that for zero mean independent, identically distributed measurement errors, the coefficient estimates can be expressed as

$$\hat{A} = (Z'Z)^{-1}\, Z'\underline{\tilde{X}} \tag{5-13}$$

where

$$\underline{\tilde{X}} = \begin{bmatrix} \tilde{X}_N(t_{N-L+1}) \\ \cdot \\ \cdot \\ \cdot \\ \tilde{X}_N(t_{N-1}) \\ \tilde{X}_N(t_N) \end{bmatrix} \qquad \hat{A} = \begin{bmatrix} \hat{a}_1(t_N) \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \hat{a}_K(t_N) \end{bmatrix}$$

$$\begin{bmatrix} Z_1(t_{N-L+1}) & \dots & Z_K(t_{N-L+1}) \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ Z_1(t_N) & \dots\dots\dots & Z_K(t_N) \end{bmatrix} \qquad A = \begin{bmatrix} a_1 \\ \cdot \\ \cdot \\ \cdot \\ a_K \end{bmatrix} \tag{5-14}$$

if $(Z'Z)^{-1}$ exists.

These estimates are unbiased, that is,

$$E\{\hat{A}\} = A \tag{5-15}$$

where $E\{\cdot\}$ denotes expectation. The variance of $\hat{A}$ is given by

$$VAR\{\hat{A}\} = (Z'Z)^{-1}\, \Gamma_\varepsilon^{\,2} \tag{5-16}$$

where $\Gamma_\varepsilon^{\,2}$ is the variance of the parameter measurement error ε_k.

In summary, a forecast of the parameter process is desired. The process to be forecast is assumed to have a known functional form, except for unknown coefficients. The coefficients are estimated using Equation 5-13 and the forecast is made using Equation 5-12.

This technique is flexible in that the functions $Z_n(\cdot)$ are not restricted as to their functional form, although the functional forms must be known. The primary disadvantages of the technique are its processing and storage requirements. A more detailed discussion of the advantages and disadvantages of the linear regression trending technique is presented in Section 5.2.4.

5.2.3.3 Moving Averages

For a processes that can be modeled as a time dependent polynomial, moving averages can be used to forecast future process realizations. A simple moving average of the observation process $\tilde{X}(.)$ can be found from the latest L observations by

$$M_N^{(1)} = \frac{1}{L} \sum_{k=N-L+1}^{N} \tilde{X}(t_k) \tag{5-16}$$

If the parameter to be forecast is a constant then $\underset{\sim}{M}_N^{(1)}$ would estimate this constant and will minimize the least squares criteria. The simple moving average can be expressed recursively as

$$M_N^{(1)} = M_{N-1}^{(1)} + \frac{\tilde{X}(t_N) - \tilde{X}(t_{N-L})}{L} \tag{5-17}$$

In a similar manner higher order moving averages can be defined as the moving average of a lower order moving average. In particular, the p^{th} order moving average is defined as

$$M_N^{(P)} = M_{N-1}^{(P)} + \frac{M_N^{(P-1)} - M_{N-L}^{(P-1)}}{L} \tag{5-18}$$

For the cases where the parameter process can be accurately represented by a time dependent polynomial, moving averages can be used to forecast

the parameter process. As an example, consider the linear parameter function

$$X(t_K) = a_1 + a_2 t_k \tag{5-19}$$

then the forecast equation is [4]

$$\hat{X}_N(t_{N+M}) = 2\,M_N^{(1)} - M_N^{(2)} + \frac{2\,T}{L-1}\left(M_N^{(1)} - M_N^{(2)}\right) \tag{5-20}$$

where $T = t_{N+M} - t_N$. In general, the order of the moving average equals the order of the polynominal model.

Thus, moving averages can be used to forecast parameter processes representable by a time dependent polynominal. Computationally, the moving average approach to trending requires little processing compared to the matrix manipulations of the linear regression technique. The storage requirements are quite large. A more detailed discussion of the advantages and disadvantages of the moving average trending technique is presented in Section 5.2.4.

5.2.3.4 Exponential Smoothing

To alleviate the storage problems associated with the moving average approach to trending, an exponential smoothing approach can be employed. In a manner similar to moving averages, a simple exponential smoothing operator can be expressed as

$$S_N^{(1)} = (1-\alpha)\; S_{N-1}^{(1)} + \alpha \tilde{X}(t_N) \tag{5-21}$$

where the fraction α is called the smoothing constant. Higher order exponential smoothing operators can be similarly defined by

$$S_N^{(P)} = (1-\alpha)\; S_{N-1}^{(P)} + \alpha S_N^{(P-1)} \tag{5-22}$$

The exponential smoothing operators can be used to trend time dependent polynominals in much the same manner as moving averages. As an example, consider the linear parameter function of Equation 3-18, the forecast equation using exponential smoothing is

$$\hat{X}_N(t_{N+M}) = \left(2 + \frac{\alpha\Upsilon}{1-\alpha}\right) S_N^{(1)} - \left(1 + \frac{\alpha\Upsilon}{1-\alpha}\right) S_N^{(2)} \tag{5-23}$$

where $\Upsilon = t_{M+N} - t_N$.

The exponential smoothing approach can be generalized. Consider the parameter process expressible as a time dependent polynomial, that is,

$$X(t) = \sum_{n=1}^{K} b_n t^{n-1} \tag{5-24}$$

To forecast $X(t)$ at time t_{N+M} it is best to express the parameter process as

$$X(t_{N+M}) = \sum_{n=1}^{K} a_n(t_N)\, \Upsilon^{n-1} \tag{5-25}$$

where $\Upsilon = t_{N+M} - t_N$. Therefore, it is sufficient to estimate $a_n(\cdot)$. Equation 5-25 represents the shifting time origin approach to trend analysis. After the $a_n(\cdot)$ are estimated, the future parameter process are estimated by

$$\hat{X}_N(t_{N+M}) = \sum_{n=1}^{K} \hat{a}_n(t_N)\, \Upsilon^{n-1} \tag{5-26}$$

where $\hat{a}_n(\cdot)$ are estimates of $a_n(\cdot)$.

It can be shown that the $\hat{a}_n(\cdot)$ that are optimal with respect to minimizing a discounted least squares error criterion are given by

$$\hat{A}(t_N) = Q^{-1} S_N \tag{5-27}$$

where

$$\hat{A}(t_N) = \begin{bmatrix} \hat{a}_1(t_N) \\ \cdot \\ \cdot \\ \cdot \\ \hat{a}_K(tN) \end{bmatrix} \qquad \begin{bmatrix} S_N^{(1)} \\ \cdot \\ \cdot \\ \cdot \\ S_N^{(K)} \end{bmatrix}$$

and Q is a matrix with elements

$$Q_{pk} = \frac{(-1)^k}{k!} \frac{\alpha^p}{(p-1)!} \sum_{j=0}^{\infty} j^k \beta^j \frac{(P-1+j)!}{j!} \tag{5-28}$$

It should be noted that Q^{-1} can be computed prior to algorithm development.

Therefore, using Equations 5-26 and 5-27, the parameter process can be forecast. The forecast using exponential smoothing is limited to time dependent polynomials. Computationally, the exponential smoothing approach to trending requires little storage and relatively simple processing. A more detailed discussion of the advantages and disadvantages of exponential smoothing is presented in Section 5.2.4.

5.2.3.5 Direct Smoothing

The moving average and exponential smoothing approaches discussed in the previous two sections smoothed the observation process to forecast the parameter process. The direct smoothing approach estimates the model coefficients directly by smoothing the current period's forecast error. The procedure is very efficient computationally and can be developed using a weighted least squares criterion. When a time dependent polynomial model is used, direct smoothing is equivalent to exponential smoothing. However, the direct smoothing technique can be applied to more complicated parameter process models such as those containing trigometric and exponential functions.

Direct smoothing assumes that the parameter process is represented by a linear combination of functions, that is,

$$X(t) = \sum_{n=1}^{K} a_n \, Z_n(t) \tag{5-29}$$

Once the coefficients a_n are estimated at time t_N then the parameter process can be forecast by

$$\hat{X}_N \, (t_{N+M}) = \sum_{n=1}^{K} \hat{a}_n(t_N) \, Z_n(t_{N+M}) \tag{5-30}$$

It has been shown that the coefficients can be recursively estimated using

$$\hat{A}(t_N) = R' \hat{A}(t_{N-1}) + H E(t_N) \tag{5-31}$$

where

$$Z(t_N) = \begin{bmatrix} Z_1(t_N) \\ \cdot \\ \cdot \\ \cdot \\ Z_k(t_N) \end{bmatrix}$$

$$Z(t_{N+L}) = R Z(t_N)$$

$$E(t_N) = \tilde{X}(t_N) - Z'(\Delta t) \hat{A}(t_{N-1})$$

$$H = \left[\sum_{j=o}^{\infty} \beta^j Z(-j\Delta t) Z'(-j\Delta t) \right]^{-1} Z(o)$$

$$\Delta t = t_k - t_{k-1}$$

and β is such that it is desirable to minimize the discounted least squares given by

$$\sum_{p=1}^{N} \beta^{(N-p)} \left[X(t_p) - \hat{X}(t_p) \right]^2 \tag{5-32}$$

Therefore, the technique is limited to the functions $Z_n(t)$ satisfying $Z(t_{N+1}) = R Z(t_N)$, where R is a time independent matrix. Thus, the variables $Z_n(t)$ are mathematical functions of time such that their values at the time t_{N+1} are simply linear combinations of the same functions evaluated at time t_N. Models containing time dependent polynomials, exponentials, and trigonometric functions meet this requirement.

The procedure outlined above is often called direct smoothing because the model parameters are updated directly instead of through the use of exponential smoothed observations.

The estimates of the model coefficients are modified each period for two reasons: one reason is to account for the shift in the time origin, the other is to update the coefficients estimates according to the current forecast error.

Direct smoothing maintains the processing and storage advantages of the exponential smoothing technique while providing a more general parameter process model representation. Section 5.2.4 will discuss the advantages and disadvantages of direct smoothing in greater detail.

5.2.3.6 Box-Jenkins

The four trending techniques discussed in the previous sections assumed that the mean of the parameter process is an independent function of time and that the observation process consists of the parameter process plus a random measurement error. This measurement error has been assumed to be independent and identically distributed from sample to sample. Frequently, the assumption of independent errors is not valid.

An approach that allows trending of observations with dependent measurement errors is the Box-Jenkins [4] approach. The basic Box-Jenkins model expresses the parameter process as

$$X(t_N) = u + \sum_{j=o}^{\infty} C_j \, \varepsilon(t_{N-j}) \tag{5-33}$$

where $\{\varepsilon(t_{N-j})$ is a sequence of independent, zero mean random variables, u is the level of the process, and C_j are the process weights. It is possible to derive many models from Equation 5-33, in the following we will discuss a few.

The first model is the autoregressive process where the current process realization is dependent upon past realizations. For example,

$$X(t_N) = u + \sum_{j-1}^{k} C_j \, X(t_{N-j}) + \varepsilon(t_N) \tag{5-34}$$

A special case of Equation 5-33 is when only a finite number of weights are nonzero. That is,

$$X(t_N) = u + \sum_{j=o}^{k} C_j \, \varepsilon(t_{N-j}) \tag{5-35}$$

A third model combines the autoregressive process with the process of Equation 5-35, giving a mixed process

$$X(t_N) = u + \sum_{J=1}^{K_1} C\, X(t_{N-j}) + \sum_{k=1}^{K_2} d_j\, \varepsilon\,(t_{N-j}) \qquad (5\text{-}36)$$

The process models discussed above have been limited to stationary parameter process models. It is possible to extend these models to nonstationary parameter processes. Consider a process that behaves as if it has no constant mean, that is, the realizations in any time interval look like realizations in any other time interval, except for the process mean. By taking the difference $X(t_N) - X(t_{N-1})$, a stationary process is created. Therefore, the models discussed above can be extended to nonstationary processes.

When using the Box-Jenkins trending approach, three basic steps are required. First, historical data must be analyzed to derive a tentative parameter process model. Next, the unknown parameters of the model must be estimated. Lastly, diagnostic checks must be performed to determine the adequacy of the model and to recommend any improvements to the model.

Once the parameter process model has been selected and the unknown parameters of that model estimated (e.g., by least squares, if applicable), the model can be used to forecast the parameter process. The forecasting can be performed incrementally by assuming that the measurement noise is zero.

The primary advantage of the Box-Jenkins approach is its flexibility to different parameter process models and its ability to treat correlated noise samples. The main disadvantages of this approach is its processing and storage requirements. The advantages and disadvantages of the Box-Jenkins trend analysis approach will be discussed in detail in Section 5.2.4.

5.2.4 Trend Analysis Technique Comparison

Section 5.2.3 discussed five techniques for performing the trend analysis fault prediction algorithm. In this section the five techniques

will be compared and the basis for recommending a technique presented. The trend analysis recommendations will be made in Section 5.2.5.

Table 5-9 shows the five trend analysis techniques and the criteria that will be evaluated to arrive at a recommended approach. Forecast accuracy indicates the ability of the technique to accurately predict future values of the parameter process. Low storage requirements reflects the desire to minimize the amount of data storage necessary to perform the trend analysis processing. Low processing requirements indicates the desire to minimize the number and type of processing operations that must be performed. Model utilization reflects the fact that some trend analysis techniques are only applicable to time dependent polynomial models, while others can be applied to more generalized process models. Reaction speed indicates the time required for a technique to react to changes in the underlying parameter process model.

The five selection criteria are weighted as to their relative importance in selecting a trend analysis technique. Three criteria were given a high (two) weight, they are: forecast accuracy, low storage requirements, and low processing complexity. Forecast accuracy is of prime importance for a trend analysis CPMAS function since it will relate to the confidence that the technical controllers have in its recommended actions. Storage is cost associated with trend analysis and is given a high weight since the trend analysis function can represent a high percentage of the easily accessible data storage of the CPMAS system. Processing complexity relates to the time required for trend analysis and the arithmetic processing functions required. Model utilization and reaction speed were given low (one) weights due to their lesser importance in selecting a trend analysis technique. Model utilization received a low weight since the parameters recommended for trending are not expected to have very complex functional representations and it is anticipated that a time dependent quadratic polynomial model will be sufficient. Due to the long term trending application envisioned, reaction speed is of lesser importance in selecting a technique.

TABLE 5-9. TREND ANALYSIS TECHNIQUE SELECTION

TECHNIQUE / CRITERIA (WEIGHTS)	FORECAST ACCURACY (2)	LOW STORAGE REQUIREMENTS (2)	LOW PROCESSING COMPLEXITY (2)	MODEL UTILIZATION (1)	REACTION SPEED (1)	TOTAL
REGRESSION	5	1	2	10	8	34
MOVING AVERAGES	10	2	10	6	8	58
EXPONENTIAL SMOOTHING	10	9	10	6	10	74
DIRECT SMOOTHING	10	10	8	7	10	73
BOX-JENKINS	10	1	2	9	8	43

Each of the candidate trend analysis techniques was rated as to its ability to satisfy the selection criteria. These ratings are shown in Table 5-9, where the ratings range from zero (0) to ten (10) with ten being the best rating. The ratings were multiplied by the criteria weights and summed to arrive at a figure of merit for each technique. The figure of merit was used to recommend the trend analysis technique presented in Section 5.2.5.

For ease of computation, the forecast accuracy of the five candidate trend analysis techniques has been evaluated 4 for a linear model, that is, modeling the parameter process (see Section 5.2.3.1) as

$$X(t_R) = a_1 + a_2 t_k \tag{5-37}$$

Figures 5-7 to 5-9 show the forecast accuracy of the candidate trend analysis techniques using the recommended [3] relationship between the number of observations of moving averages, regression, and Box-Jenkins and the smoothing constant of direct and exponential smoothing. The forecast interval indicates the number of samples into the future that the forecast is desired. As expected, the further into the future the forecast is made, then the greater the forecast error. As shown in these figures, the Box-Jenkins technique is best for small forecast intervals, while the smoothing techniques and moving averages provide the best forecast for large forecast intervals.

These figures formed the basis for the forecast accurancy ratings of Table 5-9.

Figure 5-10 presents the storage requirements for the five trend analysis techniques. As shown in this figure for a large model area exponential and direct smoothing require approximately 30K bytes as opposed to the approximately 200K bytes required by the other three techniques. The rating of the techniques to the low storage requirement criteria are presented in Table 5-9 and reflect the results of Figure 5-10.

The processing complexity of the five trend analysis techniques is quite varied in that some techniques require matrix inversions and multiplication of large matrices. The processing required by each technique

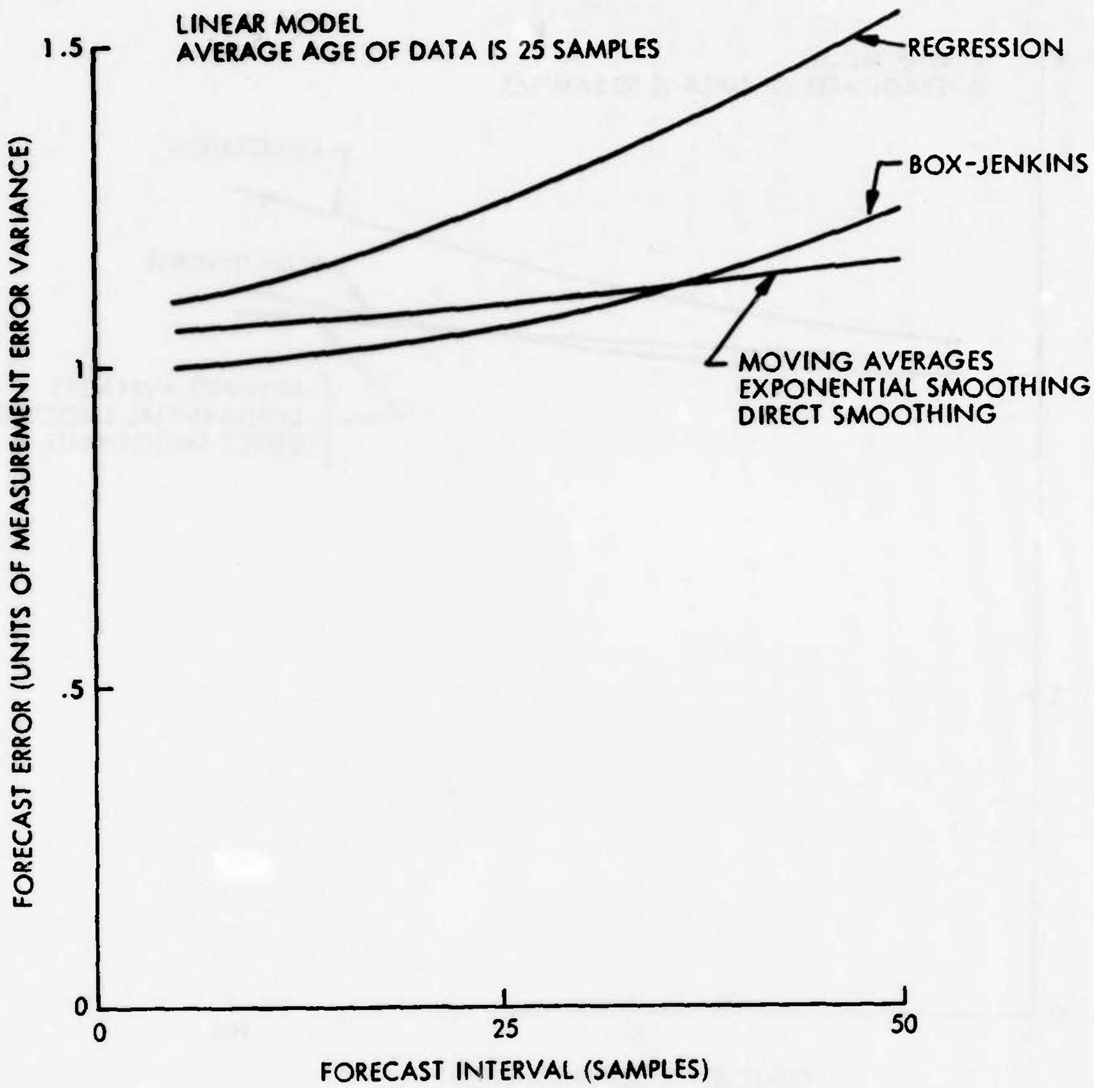


FIGURE 5-7. FORECAST ACCURACY FOR TREND ANALYSIS TECHNIQUES (DATA AGE = 25 SAMPLES)

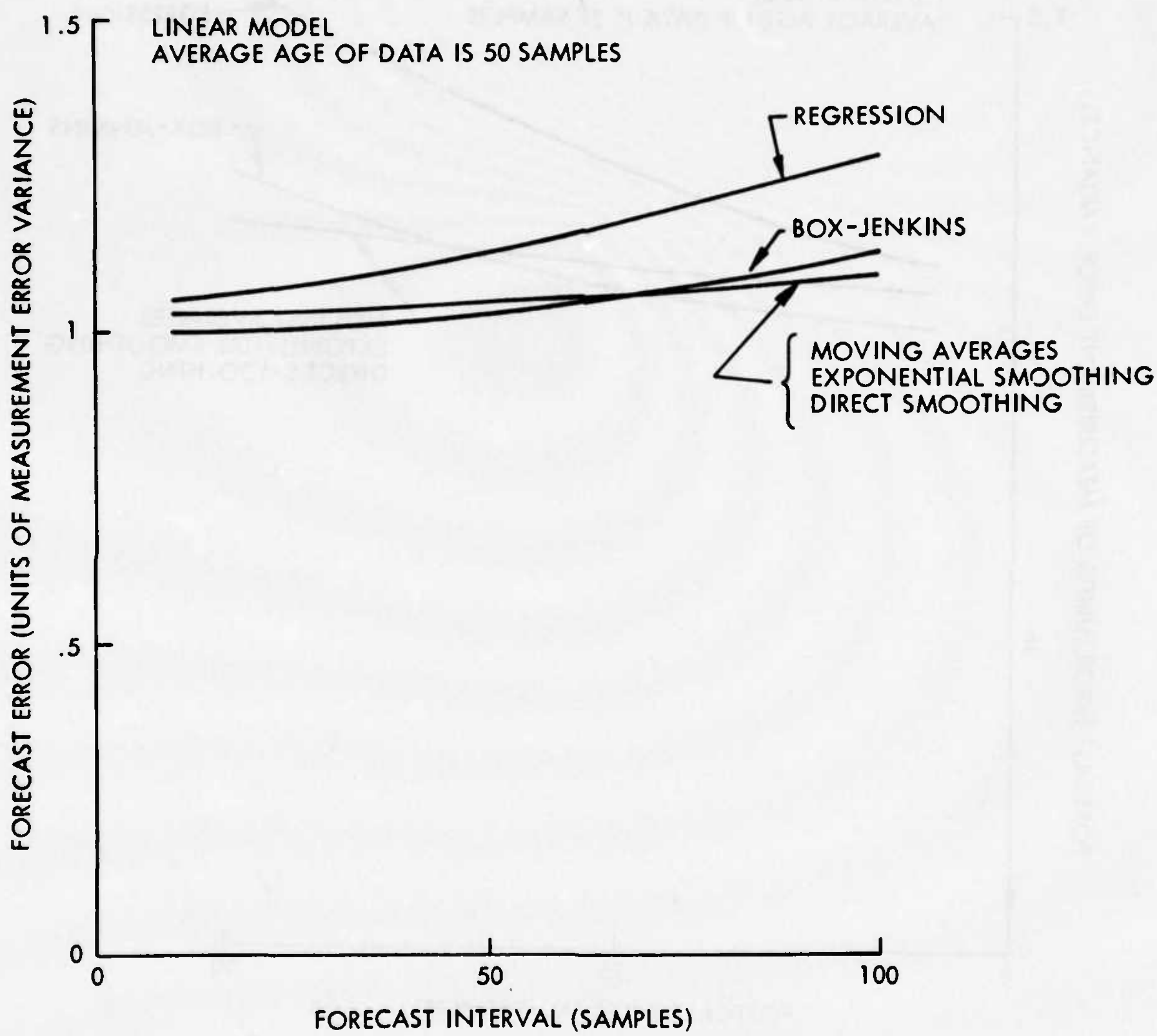


FIGURE 5-8. FORECAST ACCURACY FOR TREND ANALYSIS TECHNIQUES (DATA AGE = 50 SAMPLES)

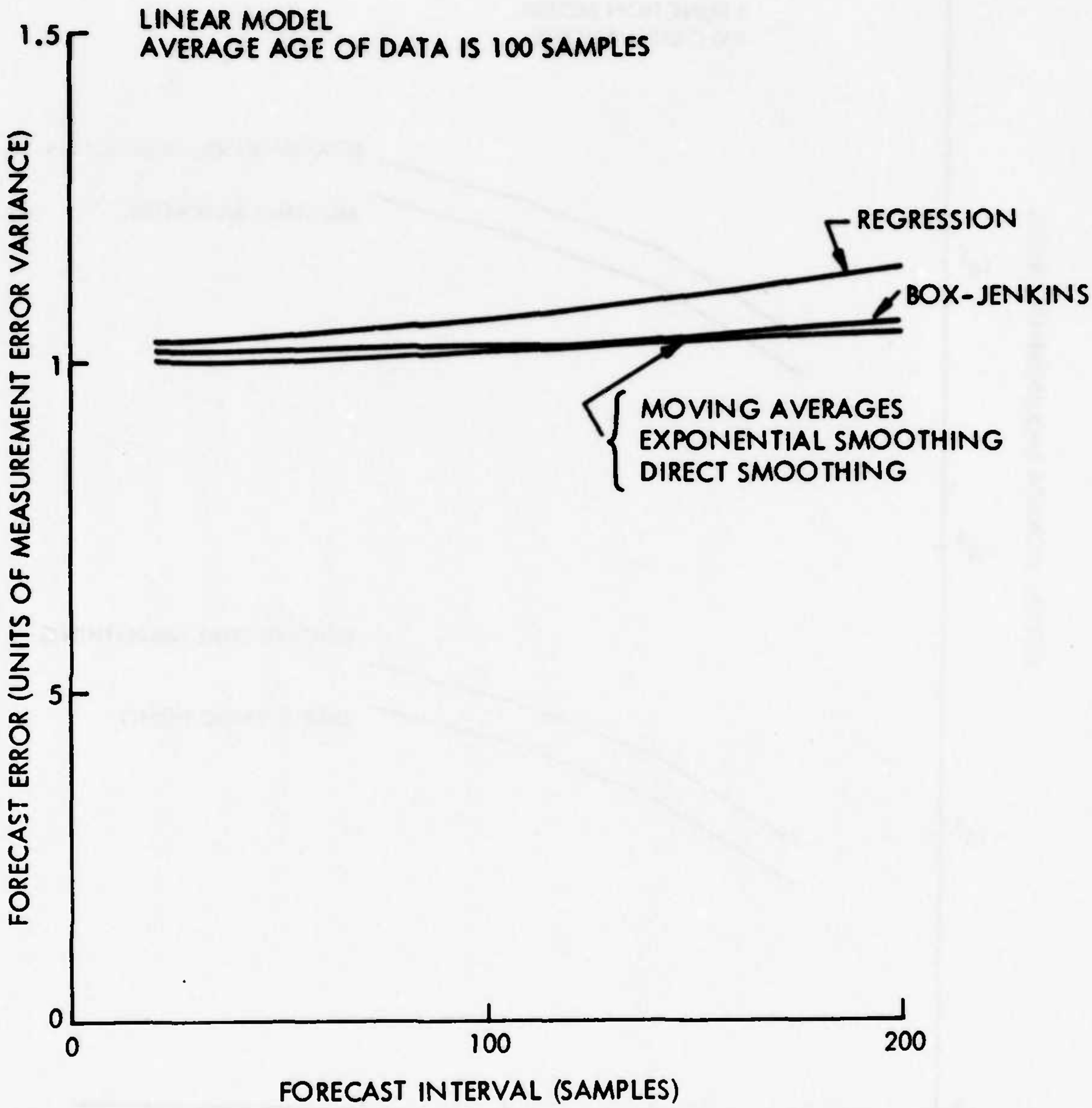


FIGURE 5-9. FORECAST ACCURACY FOR TREND ANALYSIS TECHNIQUES (DATA AGE = 100 SAMPLES)

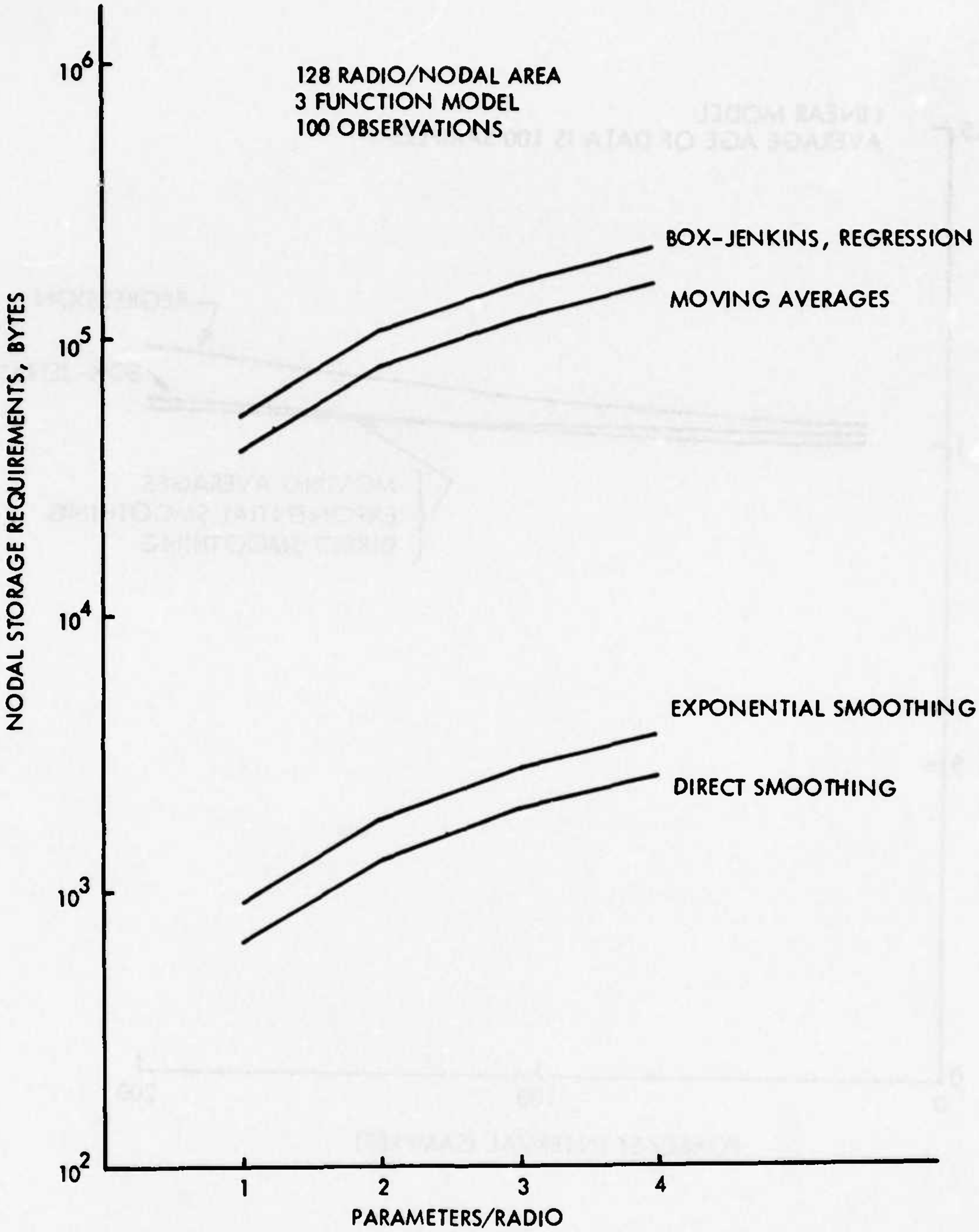


FIGURE 5-10. TREND ANALYSIS STORAGE REQUIREMENTS

is presented in the Trend Analysis Methods discussion of Section 5.2.3. Techniques requiring complex processing capability are linear regression and Box-Jenkins. On the other hand moving averages, exponential smoothing, and direct smoothing can be performed using relatively small numbers of simple arithmetic operations such as addition, subtraction, multiplication, and division. The ratings of the five trend analysis techniques with regard to processing complexity are presented in Table 5-9 and directly reflect the above discussion.

Use of the moving averages and exponential smoothing techniques are limited to time dependent polynomial models, while direct smoothing can be applied to a wider class of models (see Section 5.2.3). Box-Jenkins and linear regression can be applied to nearly all linear models as discussed in Section 5.2.3. As a quadratic polynomial model should be sufficient to model the parameters recommended for trending, then the techniques were assigned the criteria weights of Table 5-9.

Direct smoothing and exponential smoothing weight the most recent observations greater than the past observations. This increases the reaction speed of these techniques slightly over the other techniques and is reflected in Table 5-9.

5.2.5 Recommendations

The parameters to be trended were discussed and compared in Section 5.2.2. The two best parameters for trending are transmitted signal power and signal-to-distortion ratio. Signal-to-noise ratio and transmitter frequency drift were found to have the same figure of merit. Transmitter frequency drift is not recommended for trending because the number of degradations indicated by this parameter is so small. The parameters recommended for trending are transmitted signal power, signal-to-distortion ratio, and signal-to-noise ratio.

Five techniques for trending are presented in Section 5.2.3 and compared in Section 5.2.4. These techniques are existing approaches that are applicable to trending parameters of a digital transmission system. Exponential smoothing and direct smoothing were found to be the best trending

techniques for a CPMAS application. Due to exponential smoothing being more widely used, exponential smoothing is the recommended technique. For the parameters recommended to be trended, it should be sufficient to model their time variations by a quadratic polynomial. Therefore, quadratic exponential smoothing is the recommended trend analysis technique.

5.3 Fault Detection/Isolation

In the Defense Communications System (DCS), the failure or degradation of communications or communications related equipments will be designated a fault. Through proper application of performance monitoring and assessment techniques to equipments, faults will produce symptomatic signals in the form of binary alarms, analog parameters and counted events. These alarms will map a fault to an alarm characterization which is unique to that fault or group of related faults. The purpose of fault detection/isolation is to first detect the presence of these alarm conditions and then utilize a sufficient subset of the alarms to provide an inverse mapping to the causative fault within a necessary degree of resolution. This section will address requirements for automated fault analysis, techniques available and recommended approaches.

In the system under study, the process of fault analysis is complicated by several factors. The system observed is large and characterized by a mix of terminal and repeater stations of various types. Even within a particular station subclass, equipments employed and equipment configurations may differ substantially. In addition, since the DCS is in a process of evolution through equipment upgrades, characterization of individual stations will be changing. The fault analysis techniques employed must be readily adaptive to the diverse and changing characterization of nodal areas.

Because the system is large, the possibility of multiple fault occurrences in a short period of time exists. Some faults will precipitate sympathetic alarms within the station, for example the loss of a primary power source at a site would cause the occurrence of power supply alarms in all site equipments. Sympathetic alarms may also occur at other stations, for example the failure of a transmitter would cause alarm conditions at a receiver at the other end of a frequency diversity link. A sympathetic alarm will be defined as an alarm in a faultless equipment in response to a fault elsewhere in the system. The fault analysis technique chosen must be capable of processing multiple faults in an orderly manner, minimizing where possible the non-productive processing of sympathetic alarm signals.

The results from fault detection/isolation algorithms must be provided rapidly and accurately furnishing responsible personnel with a sufficient amount of information to effect repairs and restoral of lost system margin. As a minimum information furnished should include the location, time of occurrence and severity of a fault as well as a description of the faulted equipment and the level affected (i.e., link, group, channel, etc.). The fault analysis technique used must provide for identification of all this information and include in addition, analog parameters and descriptions of faulted subsystems where this would aid the controller in corrective actions.

5.3.1 Description of General Fault Analysis Techniques

The algorithms performing fault analysis can be categorized by the way in which they handle data. All fault analysis techniques can be described in terms of sequential and parallel processing techniques.

5.3.1.1 Sequential Processing Approach

In sequential processing of the database for fault analysis, parameters are examined on an item-by-item basis in order to reach decisions. A general flow diagram of actions taken in a sequential process is given in Figure 5-11.

In its simplest form, sequential processing examines each alarm independently and arrives at as many conclusions as there are variables to observe. This scheme is only useful in the detection of faults, since fault isolation in all but the simplest cases requires correlation of alarms. An example of fault detection by this means is shown in Figure 5-12.

A tree approach utilizes information present in correlated alarms and performs the functions of fault detection and isolation simultaneously. In a tree approach each alarm or monitor value is examined and a path through a decision tree is based on the state of all parameters. The number of possible outcomes, "E", is related to the number of parameters "N" by the following relation.

$$E=2^N$$

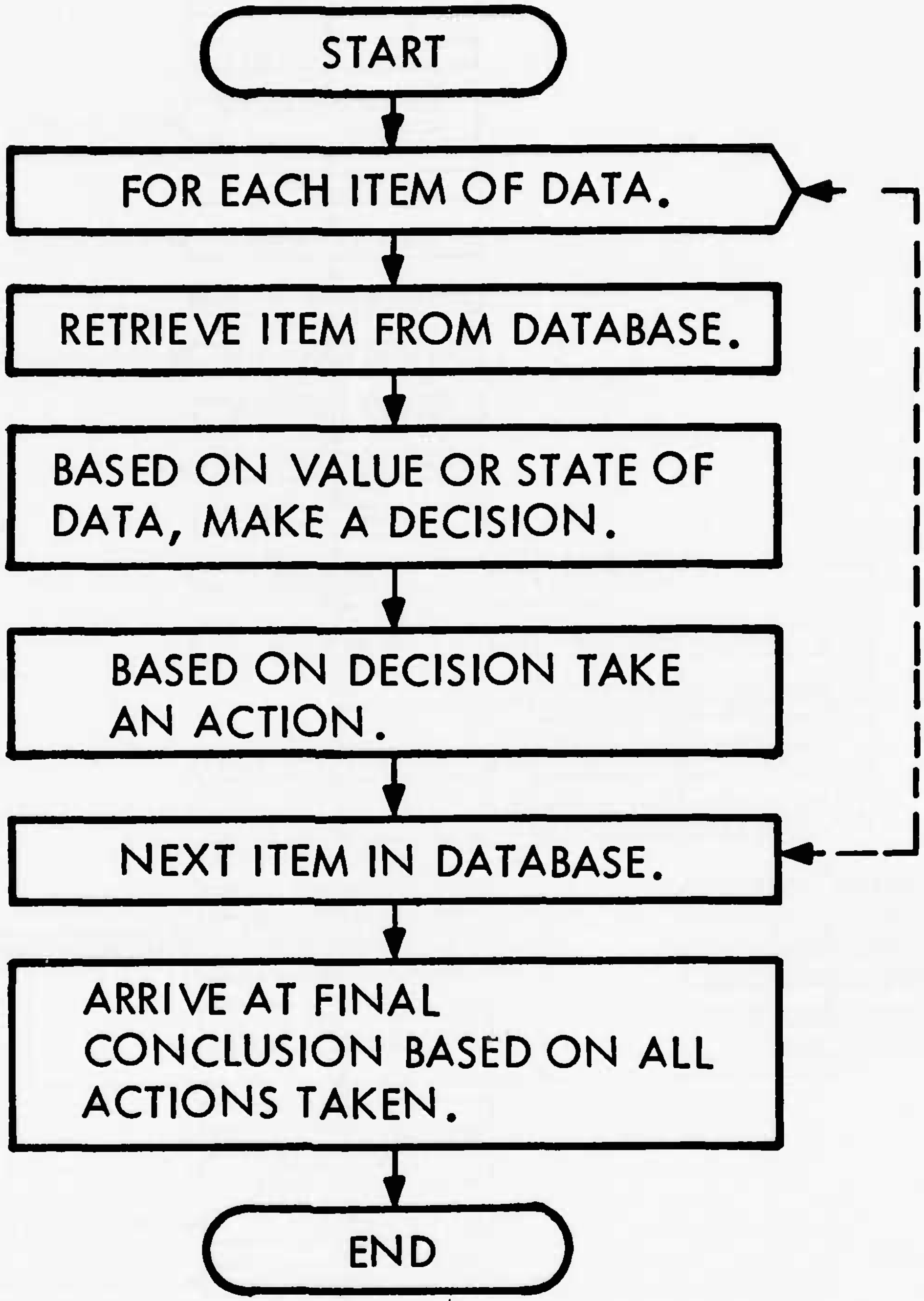


FIGURE 5-11. SEQUENTIAL PROCESSING APPROACH

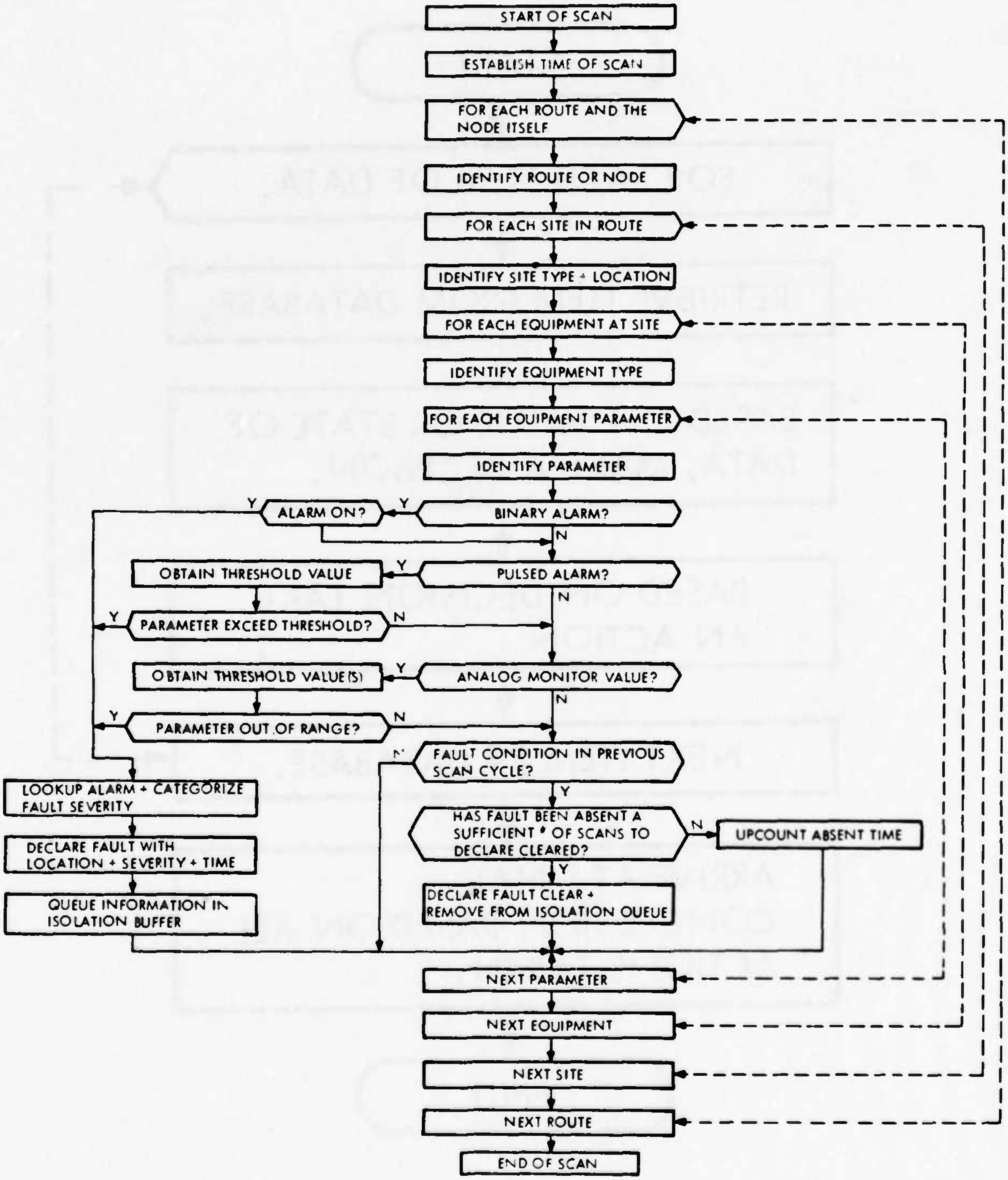


FIGURE 5-12. FAULT DETECTION VIA SEQUENTIAL PROCESSING

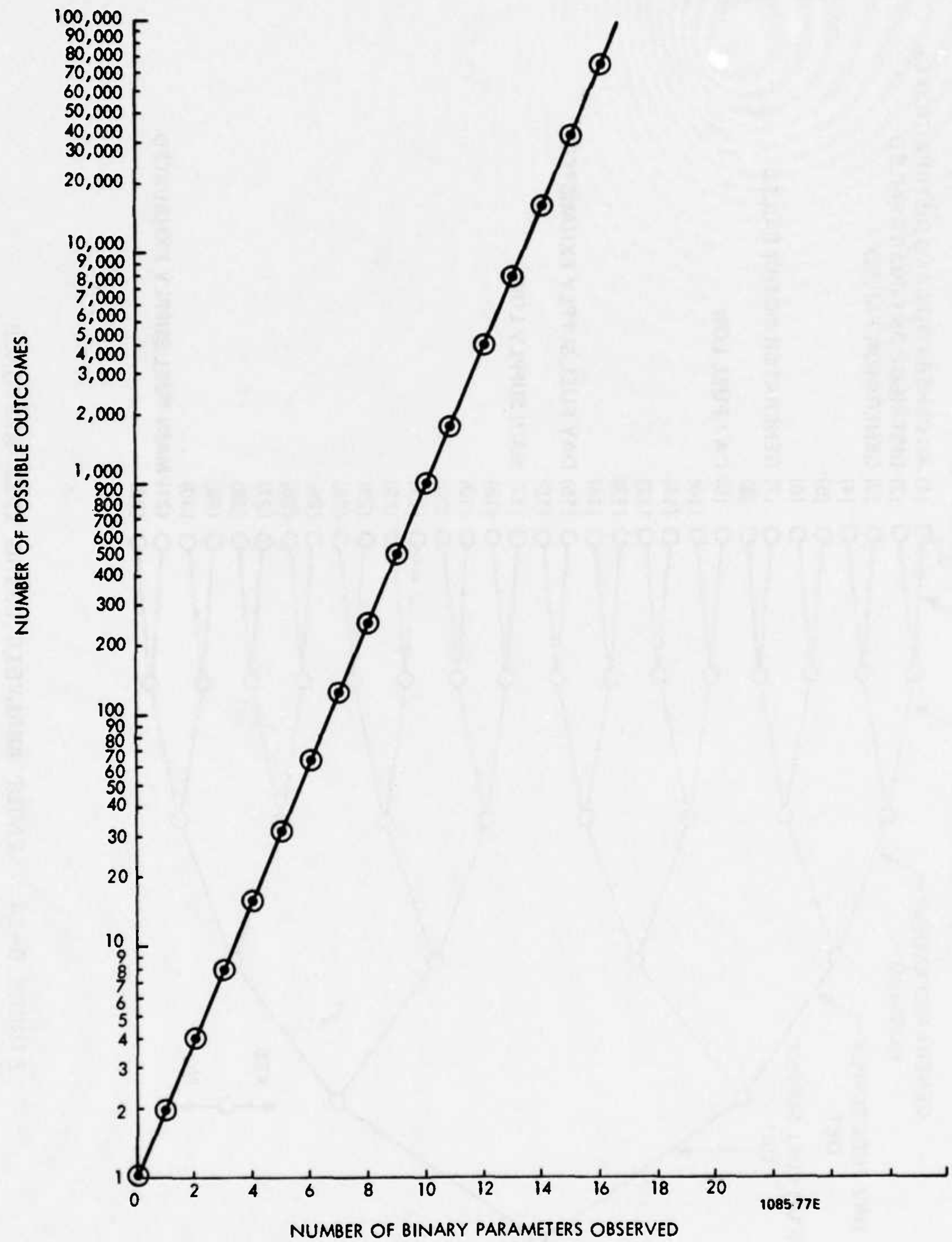


FIGURE 5-13. ILLUSTRATION OF RELATIONSHIP $E = 2^N$

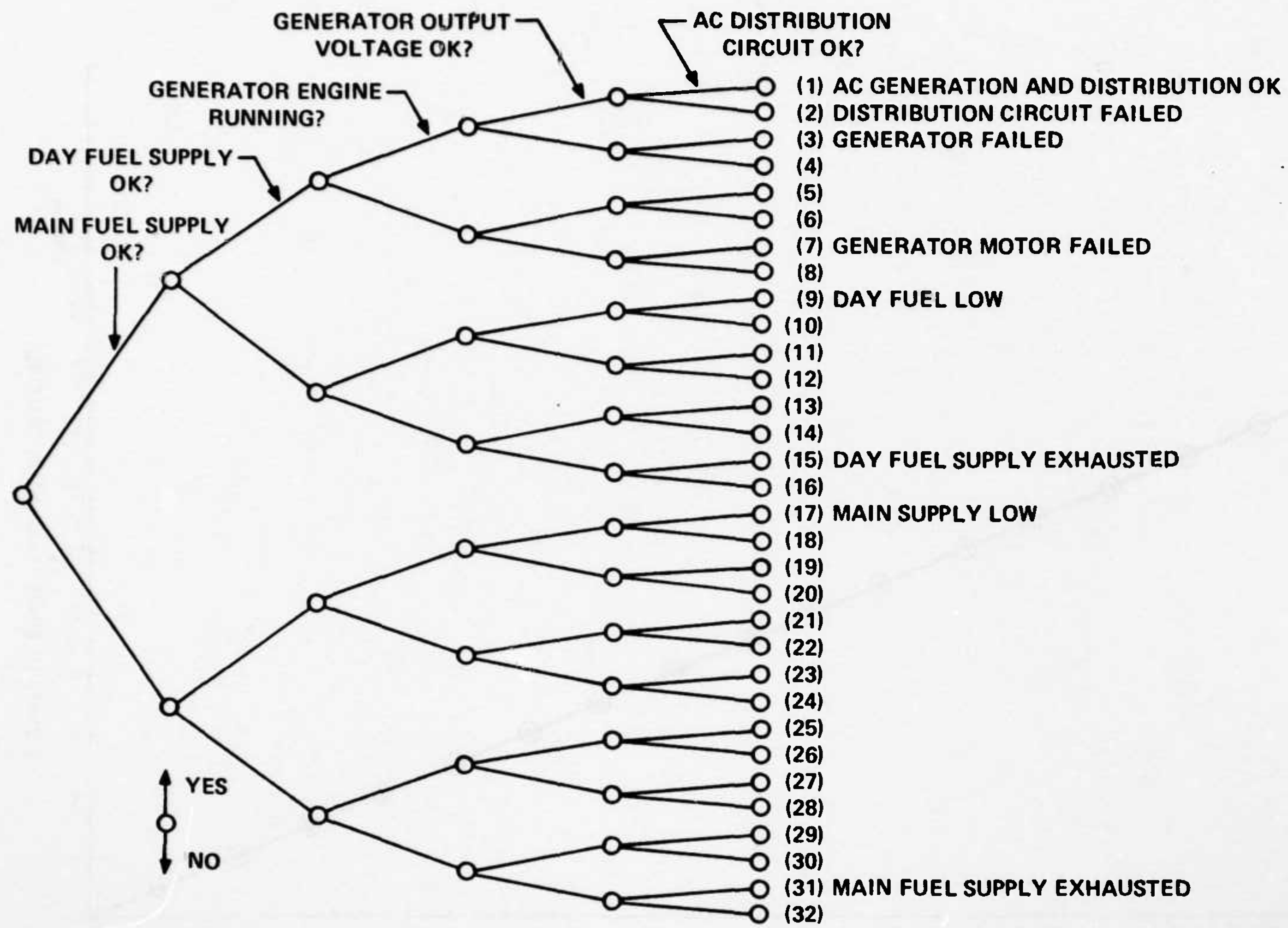


FIGURE 5-14. FAULT ANALYSIS USING TREE APPROACH

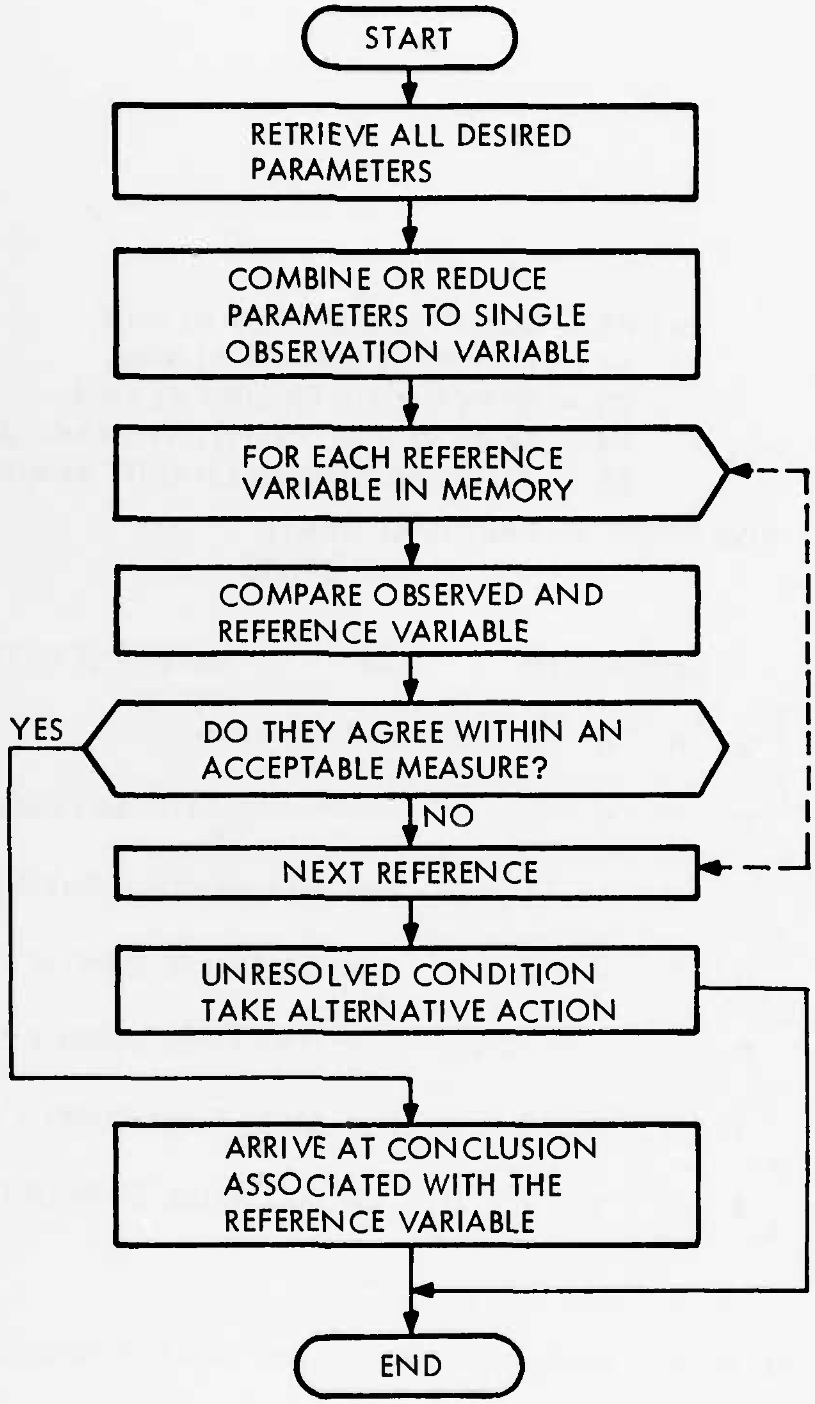


FIGURE 5-15. PARALLEL PROCESSING APPROACH

BIT #1 – MAIN FUEL SUPPLY ALARM
#2 – DAY FUEL SUPPLY ALARM
#3 – GENERATOR ENGINE ALARM
#4 – GENERATOR OUTPUT VOLTAGE ALARM
#5 – AC DISTRIBUTION CIRCUIT ALARM

FOR BITS: 0 → NORMAL STATE
1 → ALARMED STATE

SIGNATURE					⇒	INTERPRETATION
0	0	0	0	0	⇒	NO FAULTS
0	0	0	0	1	⇒	DISTRIBUTION CIRCUIT FAILED
0	0	1	1	0	⇒	GENERATOR MOTOR FAILED
0	1	0	0	0	⇒	DAY FUEL SUPPLY LOW
0	1	1	1	0	⇒	DAY FUEL SUPPLY EXHAUSTED
1	0	0	0	0	⇒	MAIN FUEL SUPPLY LOW
1	1	1	1	0	⇒	ALL FUEL EXHAUSTED

FIGURE 5-16. SIGNATURES OF COMMON FAULT CONDITIONS

SEQUENTIAL PROCESSING

- INFORMATION CONTAINED IN ALGORITHM
  - MINIMAL REFERENCE DATABASE, LONG PROGRAMS
  - FEWER I/O OPERATIONS
  - INFLEXIBLE TO CHANGES
  - HIGHLY REDUNDANT AT LOW SYSTEM LEVELS
- EXAMINATION OF INPUT VARIABLES ON AN ITEM-BY-ITEM BASIS
  - PROCESSING OF DATA NOT COMPLEX
  - ALL DECISIONS REQUIRE MAXIMUM RESOLUTION TIME

PARALLEL PROCESSING

- INFORMATION CONTAINED IN DATABASE
  - FLEXIBLE TO CHANGING SYSTEM ATTRIBUTES
  - COMMONLY ACCESSED REPRESENTATIONS OF STANDARD SYSTEM ELEMENTS REDUCE REDUNDANCY
  - LARGER REFERENCE DATABASE, SHORTER PROGRAMS
  - MORE I/O OPERATIONS
- EXAMINATION OF INPUT DATA IN A SINGLE OBSERVATION
  - RESOLUTION TIME FOR COMMON OCCURRENCES CAN BE MINIMIZED
  - MORE COMPLEX PROCESSING OF DATA

FIGURE 5-17. ATTRIBUTES OF FAULT ANALYSIS PROCESSING TECHNIQUES

This relation is illustrated in Figure 5-13. Correlation between parameters will result in the reduced likelihood of some outcomes and the baselessness of other.

A simplified example of a tree for fault detection/isolation of AC power generation and distribution is given in Figure 5-14. Five parameters are utilized in the decision and 32 outcomes are possible. Some of the outcomes are unlikely such as simultaneous occurance of generator engine failure and failure of a distribution circuit (8). While other outcomes indicate an invalid result, i.e., (5) generator engine failure concurrent with production of AC output voltage.

In a sequential approach, the majority of the knowledge or intelligence applied to the fault analysis problem is contained in the program or algorithm. Operations performed in sequential analysis are simple logical decisions and can be easily implemented. The reference database (as opposed to the input parameter database) needed is minimal and isolation of faults to a low level can be accomplished with relatively few input/output operations.

Determination of no fault conditions, however, requires as many operations as the lowest level fault isolation. Changes or modification of the system being observed will require a redefinition of the fault algorithm.

5.3.1.2 Parallel Processing Approach

A parallel approach to data processing for fault analysis is shown in Figure 5-15. There are two key aspects to the parallel processing technique, the reduction of input parameters to a single observation variable and the establishment of decision regions into which observations are mapped.

Reduction of inputs can take place in hardware or software. In a simple reduction method all input parameters either exist in a binary form or are transformed to binary alarms based on threshold exceedance. These binary signals are then applied to the inputs of an "OR" gate, and the output of the "OR" gate may then be used to indicate the presence or absence of any alarm conditions.

Another form of parallel processing for data reduction is signature formation. In its simplest form all analog values and counts of pulsed alarms would be converted to binary alarms based on exceedance of critical thresholds. These alarms are then conbined to form a pattern with the fault condition dictating the particular pattern formed. Fault patterns or signatures observed are then compared with known reference patterns. The actual combination of bits may be done in software with a program or in register. Take as an example the alarms received from the AC generation and distribution system at a site. Figure 5-16 indicates the significance of the bits in a five bit signature and some of the possible signatures with their interpretations.

In a more complex implementation of a signature analysis approach, counts of pulsed alarms and analog monitor values may be directly incorporated as input parameters. The value of each analog value and count serves to locate a co-ordinate of the signature within an "N" dimensional space, where "N" parameters are utilized. The location of the signature vector in the space and its proximity to known decision regions then establishes the type of fault present.

The other aspect of parallel processing, the formation and definition of decision regions, is dependent to some degree on the reduction approach taken. In the first case examined where all the parameters are reduced to a binary state indication, the decision rule is simple. A low output corresponds to a faultless condition and a high output from the "OR" gate defines the presence of a fault.

When binary signatures are used, a maximum of 2^N states can be defined for an "N" bit signature. For lengthy signatures a large reference vocabulary is possible. Since not all alarm signatures are possible, only a small fraction of the maximum number of signatures need to be stored. Appendix F presents estimates of the number of signatures required to be stored. Definition of signatures in the vocabulary may be accomplished by several means. A learning process for faults may be used. By inducing known fault conditions in the actual system or a simulation model, the signature produced may be identified and included in the vocabulary. The alternative to learning signatures is careful analysis of system attributes to anticipate and define signatures for given faults.

Definition of decision regions for signature vectors based on analog parameters can also be accomplished through a supervised learning process. In signatures formed from more than a few parameters, anticipation and definition of regions by analysis of system attributes may be difficult if not impossible.

In a signature form of parallel processing, information about the system being analysed is contained in a signature database. The program or algorithm to implement parallel processing provides an efficient means of accessing and utilizing this information, and need not be specifically designed for a particular system. This offers several advantages. Changes in system design do not require redefinition of algorithms and software. Changes can be accommodated through modification of or addition to the signature vocabulary. Algorithms for signature analysis can be endowed with an ability to learn, when previously undefined signatures occur and are resolved by human operators. By selective addressing of signature entries, fault processing may be optimized for minimum average isolation time or for quicker resolution of more severe faults.

The disadvantages of a signature approach relate to the storage and accessing of signatures in the database. If an attempt is made to characterize an extremely large system with a vocabulary of signatures, that vocabulary may grow beyond acceptable storage bounds. In addition, when the vocabulary is large and faults tend to be equally likely, then a large number of input/output operations may be required to resolve a fault.

5.3.1.3 Hybrid Approach

The attributes of a pure sequential or a pure parallel technique, see Figure 5-17, may be aptly suited to a well defined or small system. The system under study, however, is neither. A compromise hybrid approach which incorporates both techniques is a logical choice.

Certain aspects of the system are well defined. There will be a hierarchal structure of sectors, nodes, and stations. The stations served by a telemetry route from a node will, most likely, remain unchanged with the possibility of additional stations as the system grows. A sequential approach to examine or scan various elements within the hierarchy

would be efficient, while attempting to apply a signature approach to all the parameters at even a station level or higher would result in an unwieldy signature vocabulary.

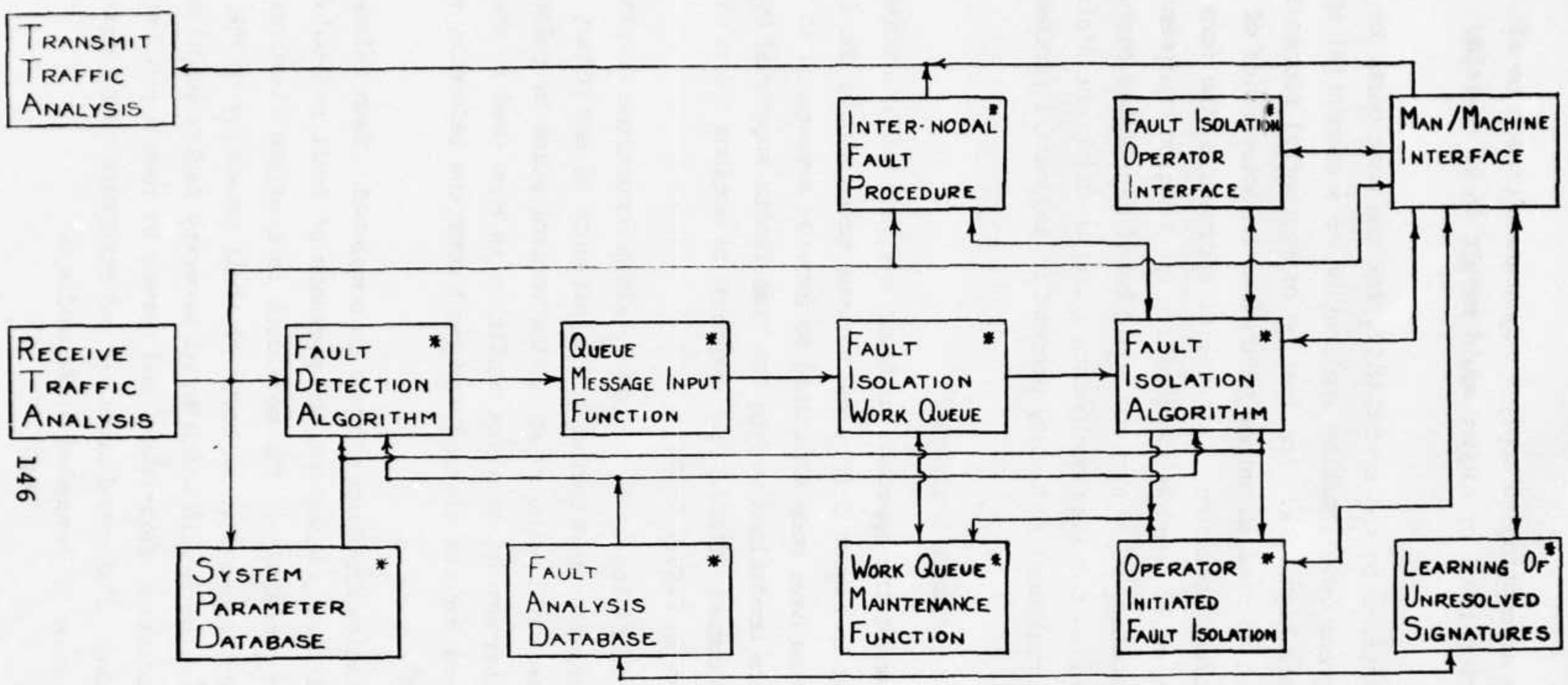
Changes and modifications to the system will, for the most part, be concentrated at the equipment level, making application of a sequential approach to alarms within equipments high risk. Application of sequential processing to equipments may not be able to take advantage of common characteristics of like equipments found in different locations. A parallel approach in the form of binary signature analysis would provide adaptability to changing equipments. At an equipment level a vocabulary of signatures would be of manageable size. Common signature vocabularies for like equipments found at different stations will also reduce the informational redundacy present in sequential processing at low system levels.

5.3.2 Candidate Approach to Fault Analysis

A functional diagram of the approach to fault analysis being studied for the CPMAS system is shown in Figure 5-18. The various tasks within the fault detection/isolation process have been separated to provide advantages in the handling of multiple alarm conditions within the time limits suggested by the Base Line Requirements Document (BLRD). The sequence of actions taken with the time limitations is shown in Figure 5-19.

Initial detection of faults as evidenced by alarm conditions occurs at the station level. The occurrence is detected by the presence of any binary alarm or the exceedance of any threshold value by an analog monitor point or pulsed alarm by the CPMAS-D. The occurrence of an alarm condition is then used to enable transmission of parameters for the alarmed equipment over the telemetry system on a "by exception basis".

At the node, the fault detection process is completed. Each telemetry route and the node itself are scanned for the presence of fault related data by receive traffic analysis processing. The node data is examined first and sites within a telemetry route are examined in order of their proximity to the node. This ordering conforms to the way in which equal severity faults would be examined in the fault isolation algorithms, and serves to reduce processing of sympathetic fault symptoms. Suggested ordering and structure to be imposed on the nodal parameter database is discussed in Appendix D.



* - ADDRESSED IN FAULT ANALYSIS STUDY

FIGURE 5-18. INTER-RELATION OF FUNCTIONS IN FAULT ANALYSIS

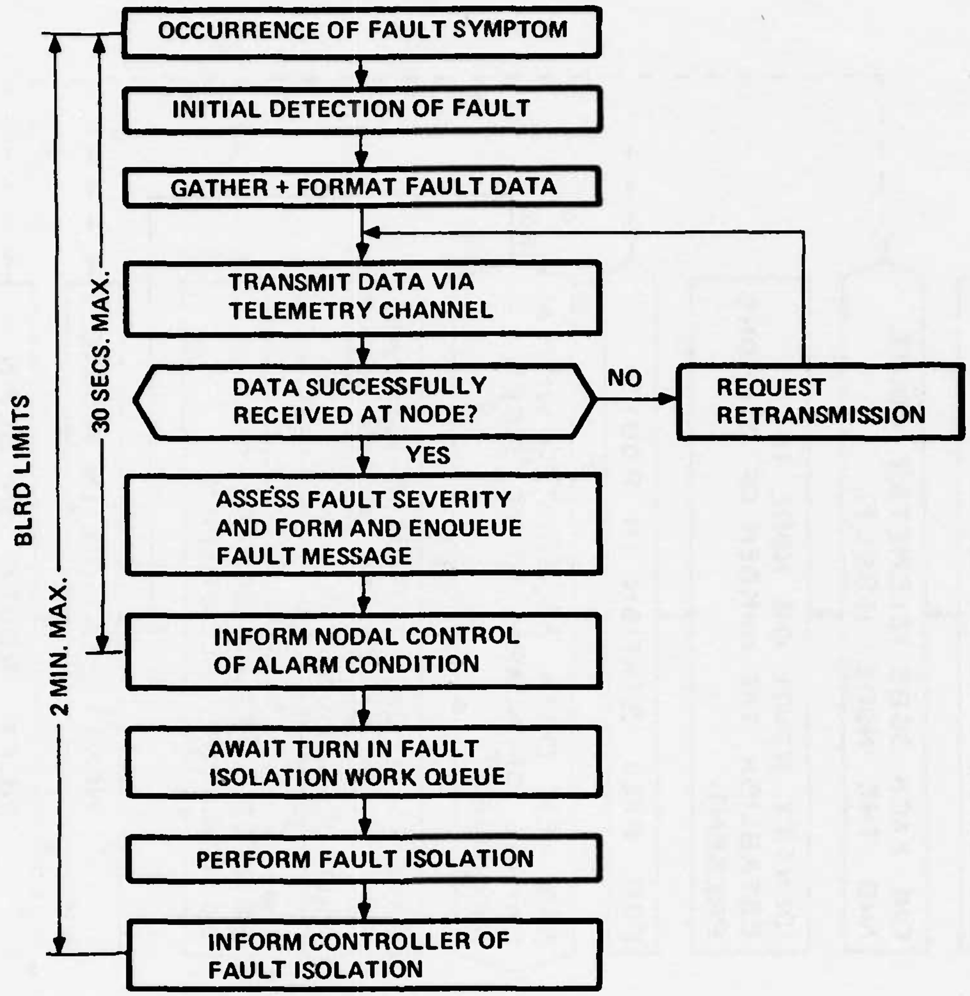


FIGURE 5-19. FAULT DETECTION/ISOLATION SEQUENCE

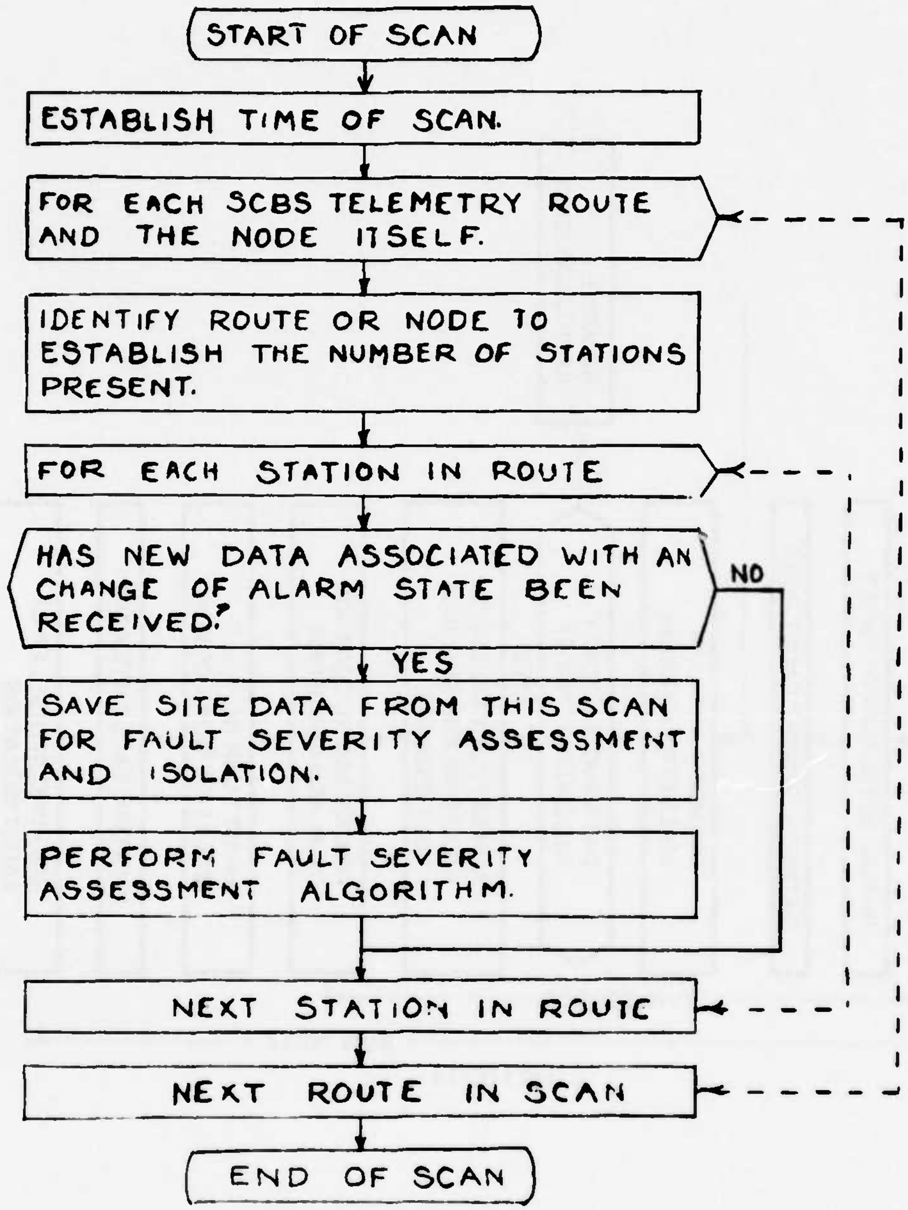


FIGURE 5-20. FAULT DETECTION PROCESS AT NODE

As indicated in Figures 5-19 and 5-20 an assessment of the fault severity must be made on the basis of alarms received from a site. The alarm conditions at the site must be categorized as either a red, an amber or a housekeeping alarm. The first two categories of alarms also require that the operator be informed.

A red alarm would be primarily distinguished by equipment failures which cause a loss of communications. This could be a failure of main and standby elements of redundant equipments or the loss of equipments vital to communication, which are not redundant. In order to detect a red alarm at a site only the parameters which reflect these conditions need be examined.

Amber alarms indicate a degradation of the system operating margin. Failure of one element in equipments with redundancy or degradation of performance of non-redundant equipment would provide the alarms for an amber condition.

Any alarms not falling into either of the above categories would be categorized as a housekeeping alarm. Housekeeping alarms would include early warnings of fuel depletion, or degradation of environmental controls at a facility. Also included in the category of housekeeping alarms would be changes of alarm states at a station indicating correction or removal of a fault.

Two approaches to assessment of fault severity are shown in Figures 5-21 and 5-22. In the first approach, key parameters are examined in a sequential manner with predetermined severities being assessed for alarms. This approach should provide rapid resolution; however, if many types of radios, mux's, etc. characterized by different alarm patterns exist, the algorithm would have many branches and would become large. The alternative approach uses a signature comparison with table look-up for the fault severity. This approach also provides rapid resolution with added storage requirements and the possibility of numerous input/output operations replacing algorithm complexity as a disadvantage.

Once the fault severity has been determined, a fault detection message would be forwarded to the fault message queuing algorithm. The message sent would indicate the location, time and severity of the alarm occurrence. A possible form for such messages is shown in Figure 5-23. Actions on incoming messages in the fault isolation queue are shown in Figure 5-24.

Another aspect of the fault message working queue would be maintenance. If faults have been resolved, then all related alarm messages will be

cleared from the work queue by assigning a low alarm status. The actual message would not be removed from the queue, since alarms will persist until the fault identified has been repaired or alleviated. Elimination of the fault is followed by the modification of alarm states at a site, transmission of new parameters to the node, and declaration of fault elimination by the fault isolation algorithm.

The final phase of fault analysis from the processing standpoint is the actual isolation process. The general framework for fault isolation is shown in Figure 5-25. The fault isolation algorithms retrieve the highest priority fault entry in the queue and the site data associated with the last time of occurrence from the database.

The data is then examined on an equipment by equipment basis. The actions taking place for an equipment are illustrated in Figure 5-26. The equipment ID data identifies the type of equipment and the configuration it is in. Based on this information the equipment parameters are formed into a signature and the signature reference vocabulary for that particular equipment is made available. The first entry in the reference library should be that of the no-fault signature. If it is established that the equipment is faulted, then a search for the observed signature is initiated.

If the observed signature is not in the reference library, then the fault was not anticipated by the system designers. While this event has a low probability, it is possible. The fault isolation algorithms in such a case must declare the fault unresolved, and a technical controller must then resolve the fault utilizing the nodal parameter database and his or her own expertise. An option in the fault isolation procedure could benefit from the work of the tech controller. The unresolved observed signature would be saved. Once the fault is resolved, the signature would be appended to the vocabulary along with its proper definition and recommendations for action. Future occurrences of this fault could then be isolated by the machine without human intervention.

When a signature in the reference library is matched to the observed signature, related information is retrieved from the database. Figure 5-27 indicates the possible information available regarding a signature. This information, which shall be designated a signature definition, may be shared

by more than one signature, if the signatures share common attributes and requirements.

If the signature observed indicates the alarm symptoms observed could be sympathetic to a fault in another equipment at the same site, an instruction to jump to another point within the isolation algorithm will be in the signature definition. If the signature may be sympathetic and relates to a fault at another site, the jump will initiate isolation in the site identified. In any action involving a jump, the last location prior to the jump will be saved. Commands to jump may also be issued when the isolation requires either operator interface or higher level (i.e., sector) co-ordination to proceed.

If the signature identified isolates the fault, the fault defined for the signature is declared. In addition, the signature definition may contain lists of parameters to be retrieved from the database as supplementary information, alarms to be suppressed in further on-site isolation, and fault messages at other sites to be inhibited or cleared.

This concludes the description of the candidate approach to fault analysis for CPMAS. A summary of the attributes of this approach is given in Figure 5-28.

5.3.3 Signatures In Fault Analysis

As indicated in the previous section, signatures will be utilized when fault analysis is performed at the equipment level. There will be signatures for fault severity assessment purposes and signatures for fault isolation purposes.

Appropriate selection of the alarms to be incorporated within a signature is crucial to the fault analysis process. If too few alarms are utilized, then the desired degree of resolution in the isolation or severity assessment will not be attained. If too many alarms are utilized in decisions, then the number of likely outcomes will become unwieldy and in fact the superfluous alarms may impede the analysis. Therefore parameters used must be restricted to meaningful combinations of equipment parameters.

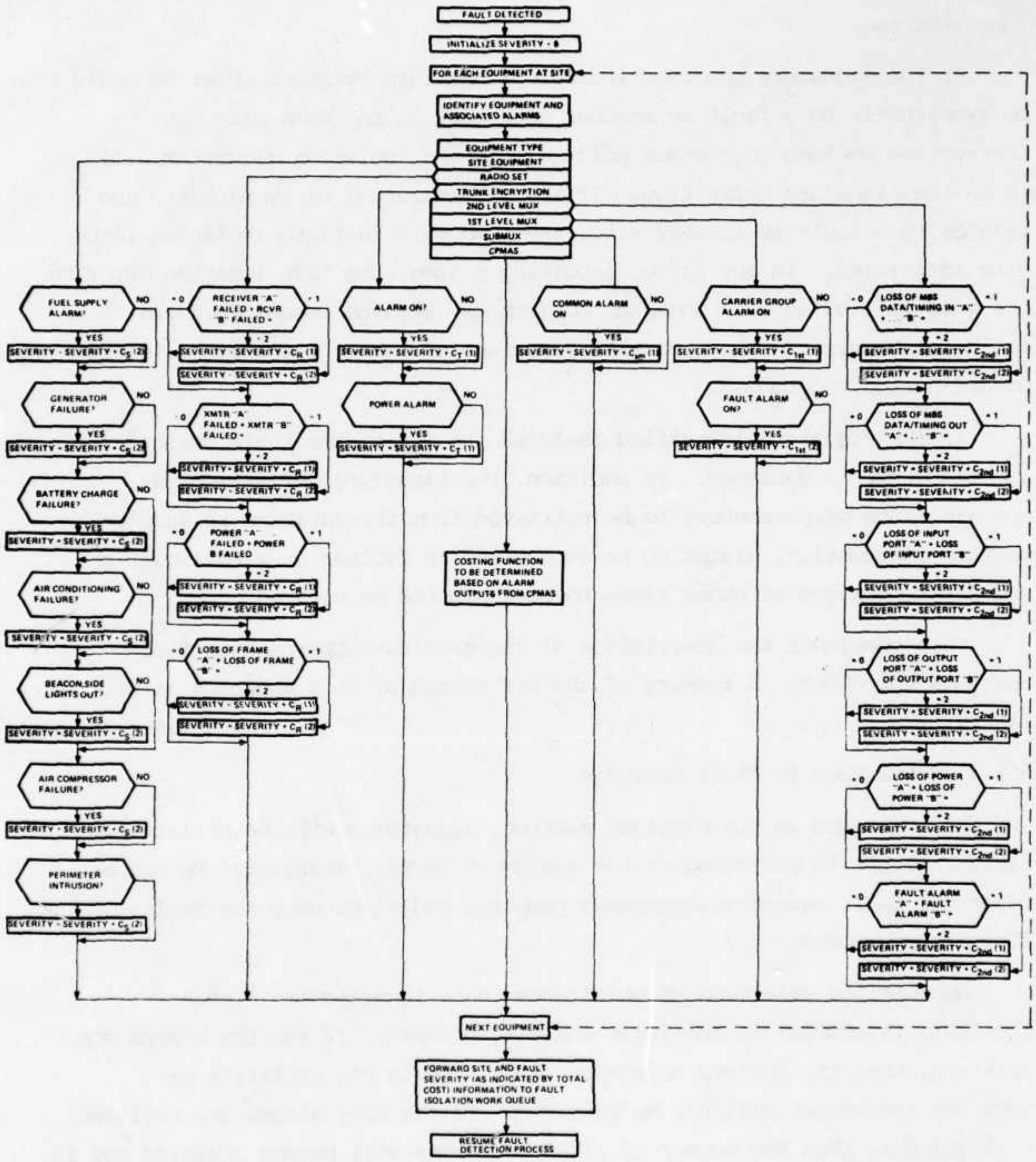


FIGURE 5-21. FAULT SEVERITY ASSESSMENT, APPROACH 1

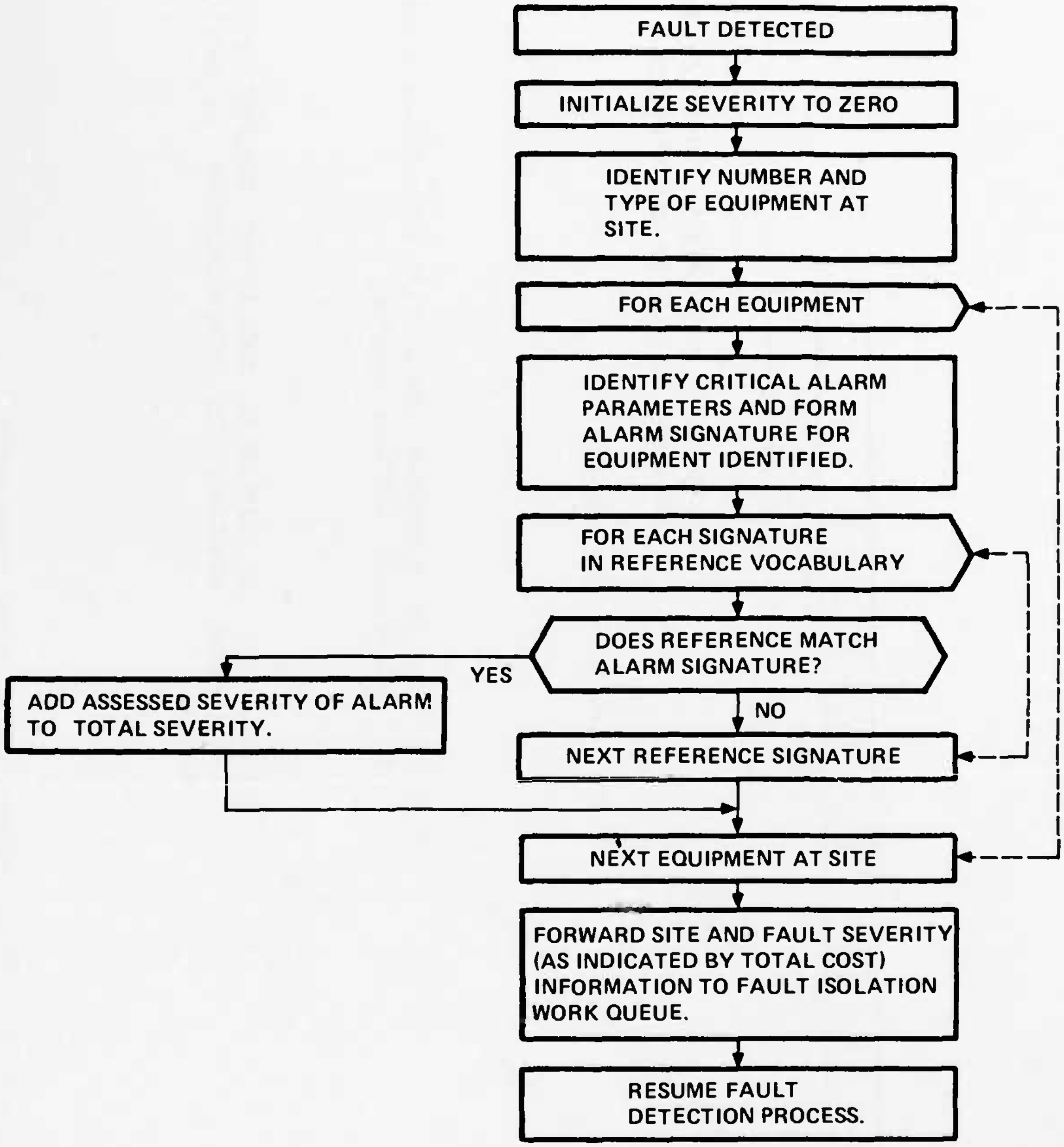


FIGURE 5-22. FAULT SEVERITY ASSESSMENT, APPROACH 2

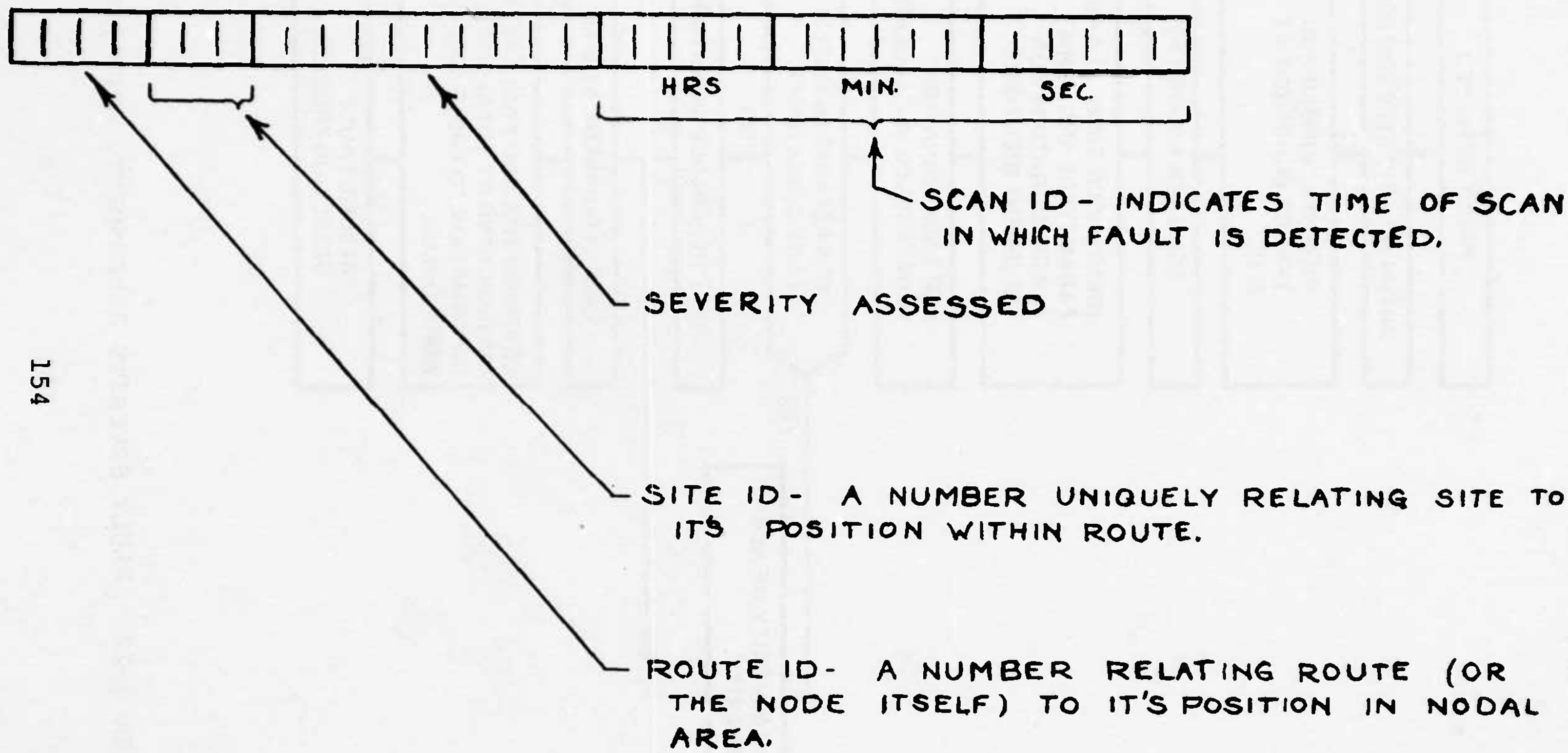


FIGURE 5-23. FAULT DETECTION MESSAGE COMPONENTS

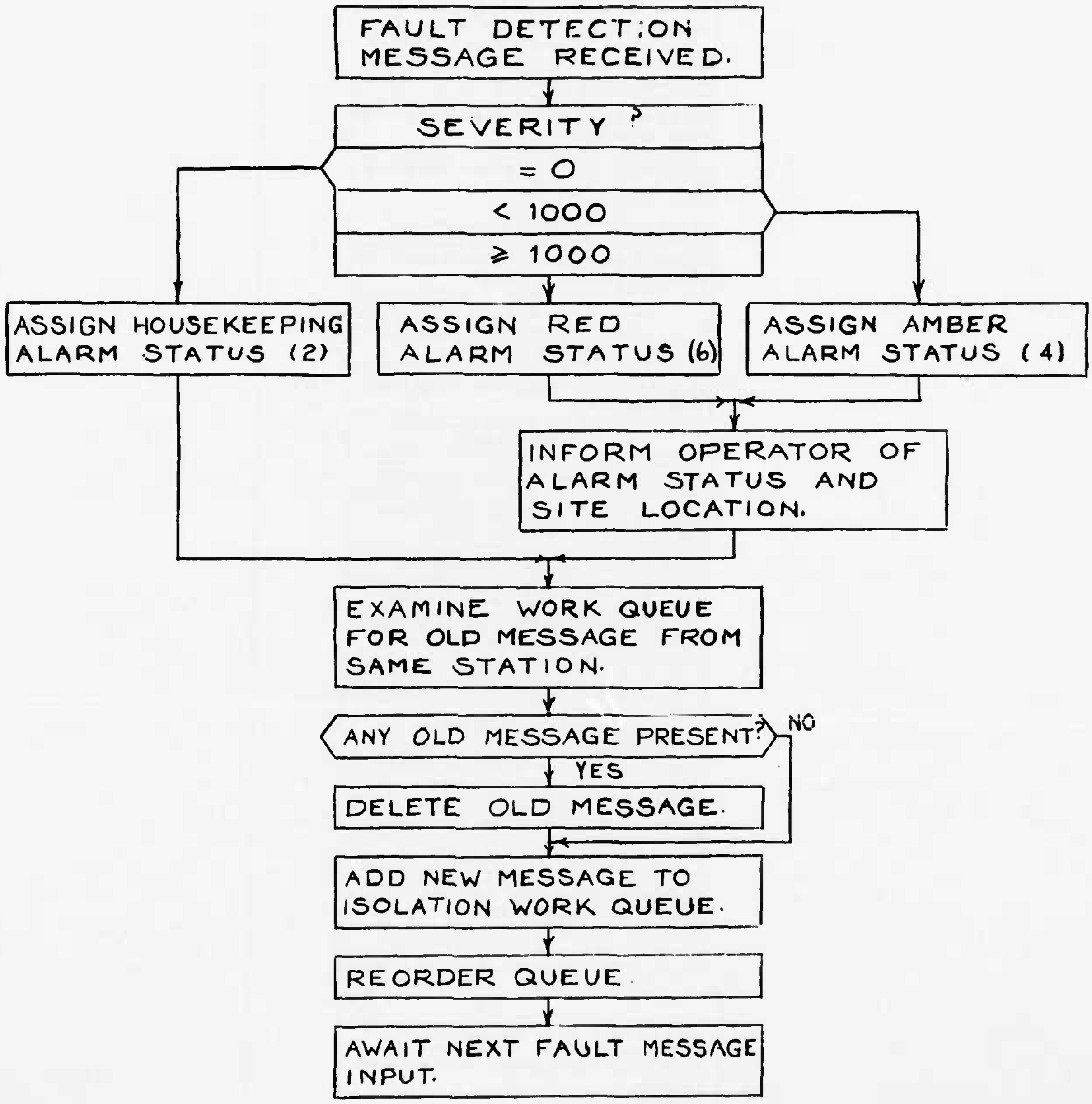


FIGURE 5-24. FAULT ISOLATION WORK QUEUE MESSAGE INPUT FUNCTION

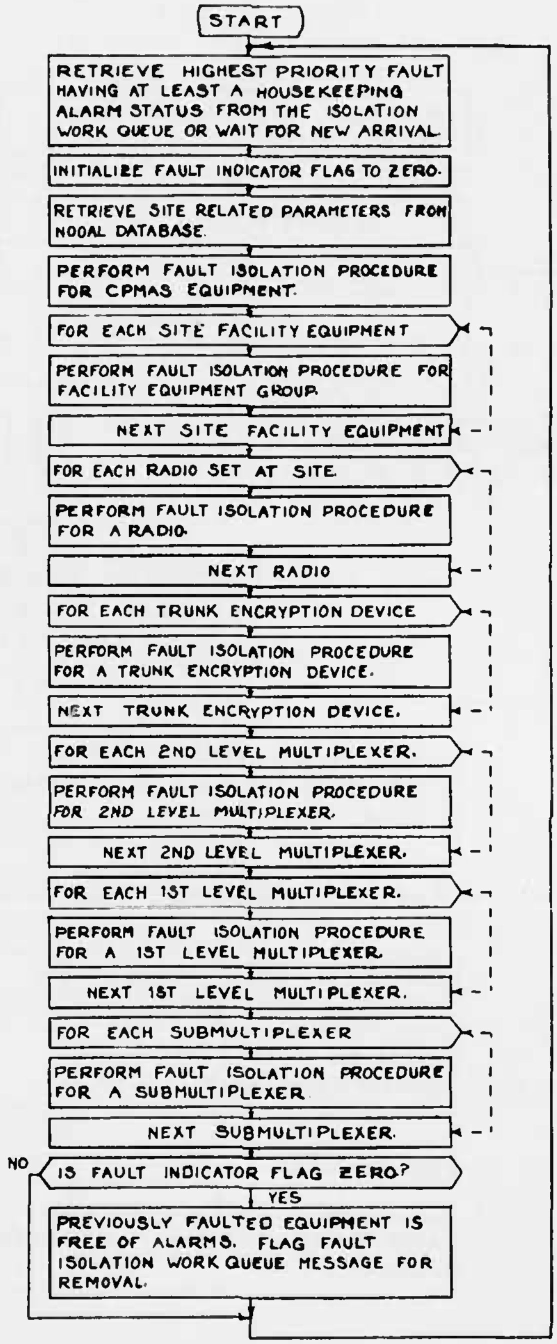


FIGURE 5-25. STRUCTURE FOR FAULT ISOLATION, EXCLUDING CORRELATION JUMPS

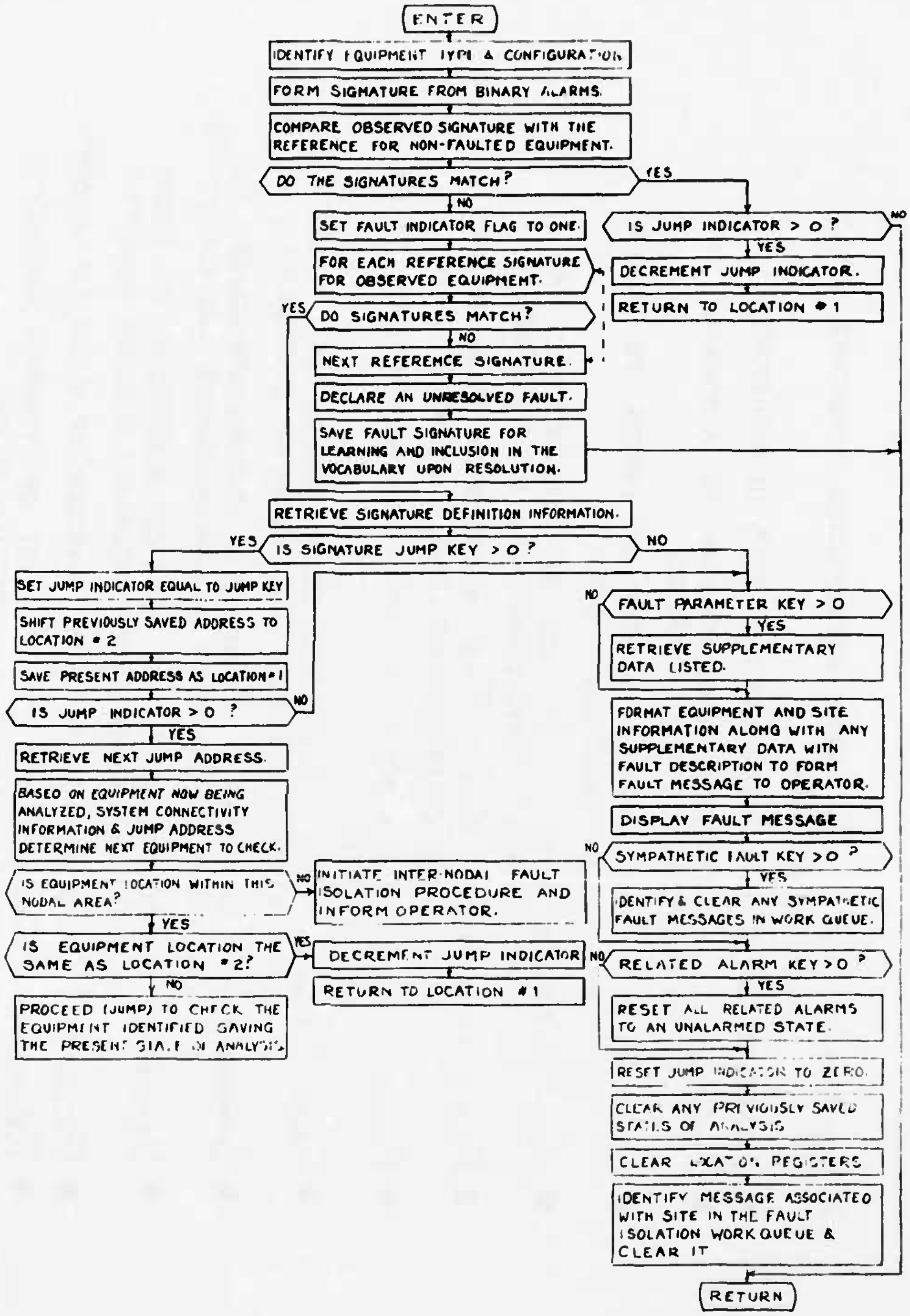


FIGURE 5-26. ISOLATION PROCEDURE FOR AN EQUIPMENT

- SIGNATURE INDEX - A NUMBER REFERENCING SIGNATURE WITHIN FAULT VOCABULARY.
- SIGNATURE LENGTH - THE NUMBER OF BITS IN SIGNATURE.
- SIGNATURE - A PATTERN CORRESPONDING TO A UNIQUE REPRESENTATION OF ALARMS.
- JUMP KEY - THE MAXIMUM NUMBER OF JUMPS TO OTHER POINTS IN FAULT ANALYSIS.
- JUMP ADDRESS LIST - A LIST OF ADDRESSES AT WHICH FAULT CONDITIONS WILL BE TESTED.
- FAULT PARAMETER KEY - THE NUMBER OF PARAMETERS NEEDED TO SUPPLEMENT FAULT DESCRIPTION.
- FAULT PARAMETER LIST - A LIST OF PARAMETERS TO BE RETRIEVED.
- FAULT DESCRIPTION - LITERAL DATA IDENTIFYING FAULT WITH PROVISION FOR INCLUSION OF SUPPLEMENTARY DATA.
- SYMPATHETIC FAULT KEY - A NUMBER CORRESPONDING TO HOW MANY SYMPATHETIC ALARM MESSAGES ARE EXPECTED.
- SYMPATHETIC FAULT LIST - A LIST OF SUBORDINATE FAULT MESSAGES FOR WHICH FAULT ISOLATION IS TO BE INHIBITED.
- RELATED ALARM KEY - THE NUMBER OF RELATED ALARMS.
- RELATED ALARM LIST - A LIST OF ALARMS RELATED TO FAULT WHICH WILL BE INHIBITED.

FIGURE 5-27. INFORMATION CONTAINED IN A SIGNATURE VOCABULARY ENTRY

- SEQUENTIAL PROCESSING AT WELL-DEFINED SYSTEM LEVELS (i.e. NODE, ROUTE, SITE)
- PARALLEL PROCESSING (SIGNATURE TECHNIQUE) AT EQUIPMENT LEVEL
- PRIORITY QUEUEING TO HANDLE MULTIPLE FAULT OCCURRENCES
- CONDITIONAL JUMPS WITHIN FAULT ISOLATION ALGORITHMS TO ISOLATE SYMPATHETICALLY ALARMED FAILURES
- CAPABILITY TO LEARN PREVIOUSLY UNRESOLVED FAULTS, OR MODIFY ERRONEOUS OR INCOMPLETE DEFINITIONS
- SUPPRESSION OF SYMPATHETIC ALARMS ON RESOLVED FAULTS

FIGURE 5-28. ATTRIBUTES OF RECOMMENDED HYBRID APPROACH

Alarms selected for severity assessment should reflect gross characteristics of faulted equipments or systems at a site. Where possible, summary alarms are utilized. Alarms indicating possible red or amber fault conditions are used, if they are not included in summary alarm conditions. Other alarms are not used. Fault severity assessment signatures for DRAMA equipments and facility are defined in Figures 5-29 to 5-32.

Alarms used in signatures for fault isolation purposes should, as much as possible, reflect specific problems within the alarmed equipment. Summary alarms directly correlated to conditions observable in other alarms will not be employed. It should be noted that alarms in addition to those identified in specifications (CCC-74047 & CCC-74048) have been recommended for the TD-1192 and TD-1193 multiplexer/demultiplexers.

For the TD-1193, 2nd level multiplexer, alarms for loss of data/timing of individual digroup inputs and outputs are suggested. The individual alarms will assure isolation to the particular digroup with a minimum of processing. The actual utility of individual port alarms is evident in the examples given later in Section 5.3.5.

In the TD-1192, 1st level multiplexer, alarming on the digital channels is recommended. These ports may be interconnected to other digital equipments which are served by the CPMAS and isolation of faults at these levels will require the suggested alarming.

Signatures for fault isolation are defined in Figures 5-33 to 5-38.

Signatures for equipments at alarmed sites are used in the equipment fault isolation procedure as shown in Figure 5-26. It is the definition of the matched reference signature, Figure 5-27, that either locates the fault to the observed equipment or redirects the analysis elsewhere. Estimates for the number of signatures and signature definitions needed for radio and mux's is given in Appendix F.

5.3.4 Ancillary Functions In Fault Analysis

As shown in Figure 5-18, a number of ancillary functions are required for fault analysis. These include processing of faults which transgress nodal boudaries, initiation of fault analysis upon operator demand, and learning of

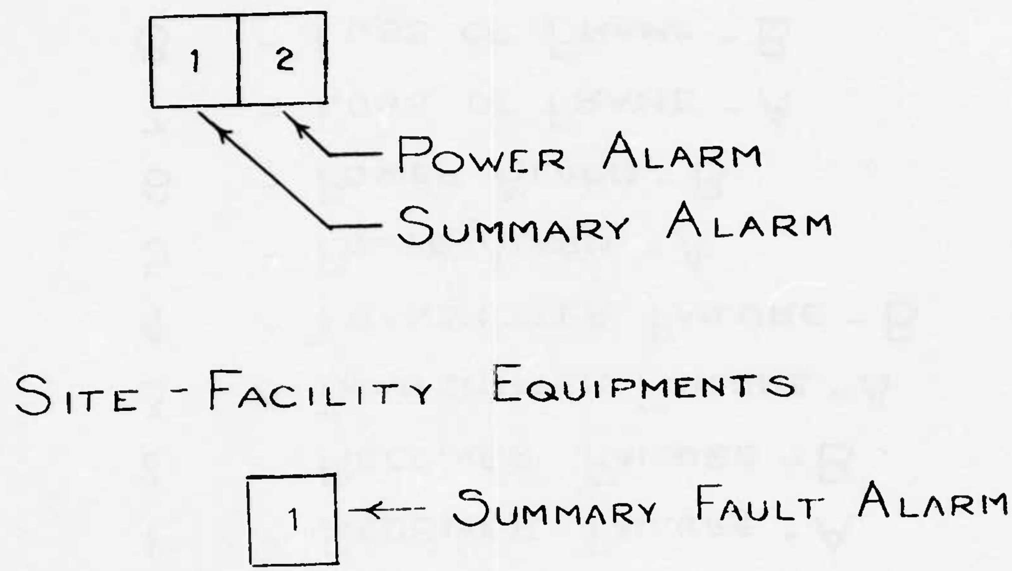


FIGURE 5-29. FAULT SEVERITY ASSESSMENT SIGNATURES KG-81 TRUNK ENCRYPTION DEVICE

1	2	3	4	5	6	7	8

BIT NUMBER SIGNIFICANCE

1 - RECEIVER FAILURE - A

2 - RECEIVER FAILURE - B

3 - TRANSMITTER FAILURE - A

4 - TRANSMITTER FAILURE - B

5 - POWER ALARM - A

6 - POWER ALARM - B

7 - LOSS OF FRAME - A

8 - LOSS OF FRAME - B

FIGURE 5-30. FAULT SEVERITY ASSESSMENT SIGNATURE FOR AN/FRC 163 RADIO SET

1	2	3	4	5	6	7	8	9	10	11	12

BIT NUMBER	SIGNIFICANCE
1	- LOSS OF MBS DATA/TIMING IN - A
2	- LOSS OF MBS DATA/TIMING IN - B
3	- LOSS OF MBS DATA/TIMING OUT - A
4	- LOSS OF MBS DATA/TIMING OUT - B
5	- LOSS OF ANY DIGROUP DATA/TIMING IN - A
6	- LOSS OF ANY DIGROUP DATA/TIMING IN - B
7	- LOSS OF ANY DIGROUP DATA/TIMING OUT - A
8	- LOSS OF ANY DIGROUP DATA/TIMING OUT - B
9	- LOSS OF POWER SUPPLY - A
10	- LOSS OF POWER SUPPLY - B
11	- FAULT ALARM - A
12	- FAULT ALARM - B

FIGURE 5-31. FAULT SEVERITY ASSESSMENT SIGNATURE FOR 2ND LEVEL MUX TD 1193

1	2	3

BIT NUMBER	SIGNIFICANCE
1	- CARRIER GROUP ALARM
2	- LOSS OF ANY DIGITAL CHANNEL
3	- FAULT ALARM

FIGURE 5-32. FAULT SEVERITY ASSESSMENT SIGNATURE FOR 1ST LEVEL MUX TD-1192

1	2	3	4	5	6	7	8

Bit Number	Significance
1	Main Fuel Supply Alarmed.
2	Day Fuel Supply Alarmed.
3	Generator Engine Alarmed.
4	Generator Output Voltage Alarmed.
5	Any AC Distribution Circuit Alarmed.
6	Battery Charger Alarmed.
7	Battery Voltage Level Alarmed.
8	Any DC Distribution Circuit Alarmed.

FIGURE 5-33. FAULT ISOLATION SIGNATURE FOR POWER GENERATION SYSTEM

1	2	3	4

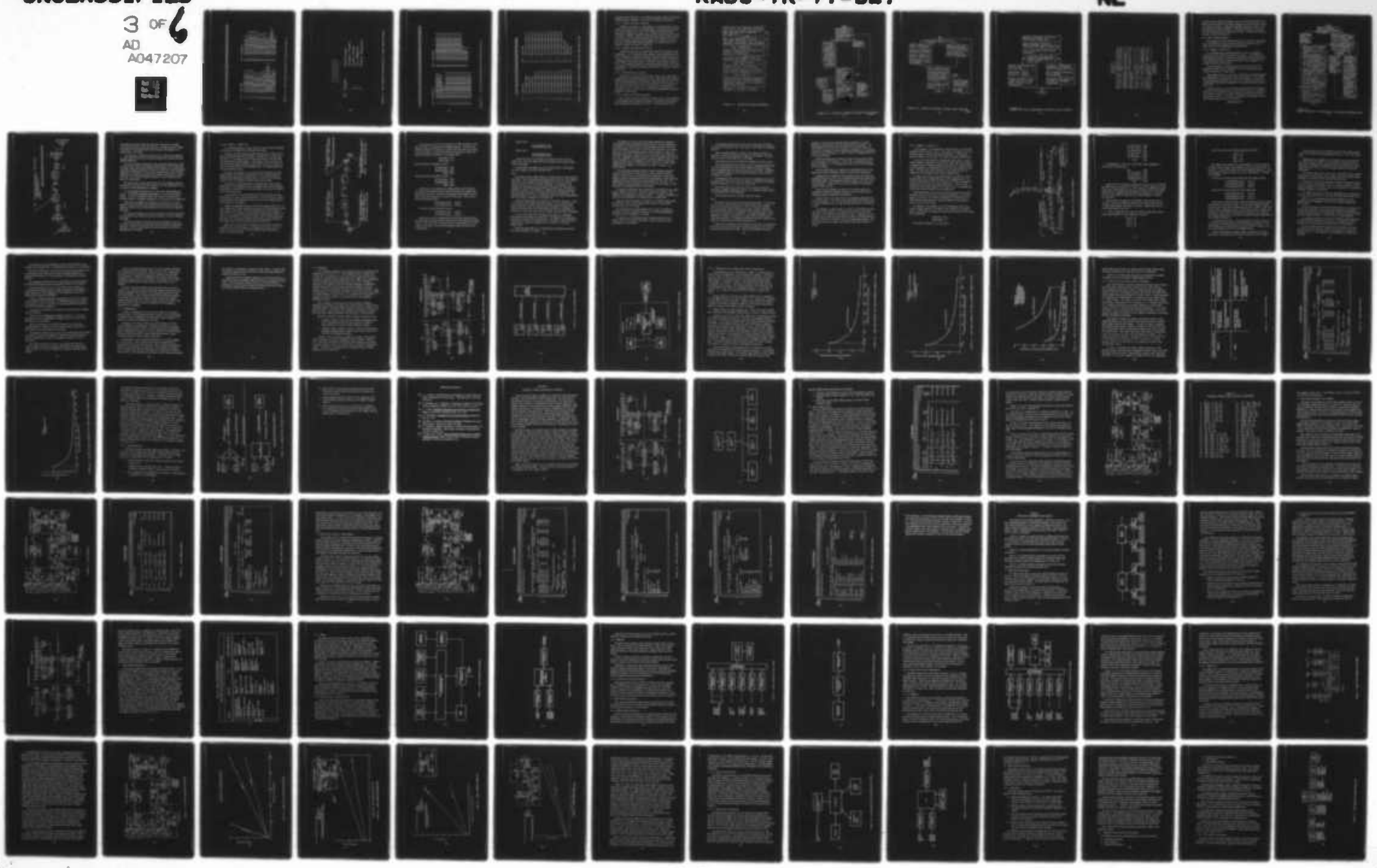
Bit Number	Significance
1	Air Compressor Alarmed.
2	Wave Guide Air Pressure Alarmed.
3	VSWR Alarmed.
4	Tower Beacon Or Sidelight Alarmed.

FIGURE 5-34. FAULT ISOLATION SIGNATURE FOR RF DISTRIBUTION SYSTEM

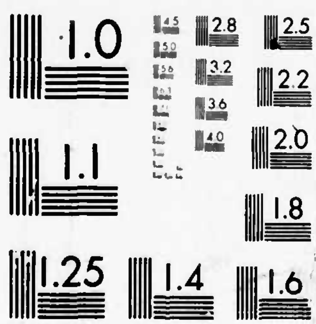
AD-A047 207 GTE SYLVANIA INC NEEDHAM HEIGHTS MASS ELECTRONIC SYS--ETC F/G 9/6
AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL--ETC(U)
OCT 77 F30602-76-C-0433

UNCLASSIFIED RADC-TR-77-327 NL

3 OF 6
AD
A047207



0472



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Bit #		Significance	Bit #		Significance
1	-	Loss of timing in port 1 - A	21	-	Bit error rate alarm - A
2	-	Loss of timing in port 1 - B	22	-	Bit error rate alarm - B
3	-	Loss of timing in port 2 - A	23	-	Loss of timing out port 1 - A
4	-	Loss of timing in port 2 - B	24	-	Loss of timing out port 1 - B
5	-	Loss of timing in port 3 - A	25	-	Loss of timing out port 2 - A
6	-	Loss of timing in port 3 - B	26	-	Loss of timing out port 2 - B
7	-	Loss of MBS in port 1 - A	27	-	Loss of timing out port 3 - A
8	-	Loss of MBS in port 1 - B	28	-	Loss of timing out port 3 - B
9	-	Loss of MBS in port 2 - A	29	-	Loss of MBS out port 1 - A
10	-	Loss of MBS in port 2 - B	30	-	Loss of MBS out port 1 - B
11	-	Loss of SCBS in port 3 - A	31	-	Loss of MBS out port 2 - A
12	-	Loss of SCBS in port 3 - B	32	-	Loss of MBS out port 2 - B
13	-	Loss of modulator output - A	33	-	Loss of SCBS out port 3 - A
14	-	Loss of modulator output - B	34	-	Loss of SCBS out port 3 - B
15	-	Transmitter frequency drift alarm - A	35	-	Receiver AFC alarm - A
16	-	Transmitter frequency drift alarm - B	36	-	Receiver AFC alarm - B
17	-	Transmitter power alarm - A	37	-	Loss of frame synchronization - A
18	-	Transmitter power alarm - B	38	-	Loss of frame synchronization - B
19	-	Loss of demodulator output - A	39	-	Loss of power supply - A
20	-	Loss of demodulator output - B	40	-	Loss of power supply - B

FIGURE 5-35. FAULT ISOLATION SIGNATURE FOR RADIO SET AN/FRC 163

1	2	3	4

Bit Number	Significance
1	Summary Alarm
2	Power Alarm
3	Full Operate
4	Resync Achieved

FIGURE 5-36. FAULT ISOLATION SIGNATURE FOR KG-81 TRUNK ENCRYPTION DEVICE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42

Bit #		Significance	Bit #		Significance
1	-	Loss of MBS data/timing out -A	23	-	Loss of digroup output port 1 - A
2	-	Loss of MBS data/timing out -B	24	-	Loss of digroup output port 1 - B
3	-	Loss of MBS data/timing in -A	25	-	Loss of digroup output port 2 - A
4	-	Loss of MBS data/timing in -B	26	-	Loss of digroup output port 2 - B
5	-	Loss of frame - A	27	-	Loss of digroup output port 3 - A
6	-	Loss of frame - B	28	-	Loss of digroup output port 3 - B
7	-	Loss of digroup input port 1 - A	29	-	Loss of digroup output port 4 - A
8	-	Loss of digroup input port 1 - B	30	-	Loss of digroup output port 4 - B
9	-	Loss of digroup input port 2 - A	31	-	Loss of digroup output port 5 - A
10	-	Loss of digroup input port 2 - B	32	-	Loss of digroup output port 5 - B
11	-	Loss of digroup input port 3 - A	33	-	Loss of digroup output port 6 - A
12	-	Loss of digroup input port 3 - B	34	-	Loss of digroup output port 6 - B
13	-	Loss of digroup input port 4 - A	35	-	Loss of digroup output port 7 - A
14	-	Loss of digroup input port 4 - B	36	-	Loss of digroup output port 7 - B
15	-	Loss of digroup input port 5 - A	37	-	Loss of digroup output port 8 - A
16	-	Loss of digroup input port 5 - B	38	-	Loss of digroup output port 8 - B
17	-	Loss of digroup input port 6 - A	39	-	Loss of power - A
18	-	Loss of digroup input port 6 - B	40	-	Loss of power - B
19	-	Loss of digroup input port 7 - A	41	-	Fault alarm - A
20	-	Loss of digroup input port 7 - B	42	-	Fault alarm - B
21	-	Loss of digroup input port 8 - A			
22	-	Loss of digroup input port 8 - B			

FIGURE 5-37. FAULT ISOLATION SIGNATURE FOR 2ND LEVEL MUX TD-1193

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Bit #	Significance	Bit #	Significance
1 -	Loss of digroup output	16 -	Loss of digital channel out 1
2 -	Loss of digroup input	17 -	Loss of digital channel out 2
3 -	Loss of frame (demux)	18 -	Loss of digital channel out 3
4 -	Loss of digital channel in 1	19 -	Loss of digital channel out 4
5 -	Loss of digital channel in 2	20 -	Loss of digital channel out 5
6 -	Loss of digital channel in 3	21 -	Loss of digital channel out 6
7 -	Loss of digital channel in 4	22 -	Loss of digital channel out 7
8 -	Loss of digital channel in 5	23 -	Loss of digital channel out 8
9 -	Loss of digital channel in 6	24 -	Loss of digital channel out 9
10 -	Loss of digital channel in 7	25 -	Loss of digital channel out 10
11 -	Loss of digital channel in 8	26 -	Loss of digital channel out 11
12 -	Loss of digital channel in 9	27 -	Loss of digital channel out 12
13 -	Loss of digital channel in 10	28 -	Power supply alarm
14 -	Loss of digital channel in 11	29 -	Loopback alarm
15 -	Loss of digital channel in 12	30 -	Fault alarm

FIGURE 5-38. FAULT ISOLATION SIGNATURE FOR 1ST LEVEL MUX TD-1192

unresolved fault signatures. The following paragraphs along with functional diagrams indicate responses to these and other analysis requirements.

5.3.4.1 Actions for Operator Interface

Information contained in a jump address of a signature definition may indicate that human decision or acknowledgement is required before analysis may proceed automatically. This may be a decision to perform remote switching of redundant equipments, where possible performance penalties may be incurred. Operator interface may also be required when alarms indicate that the integrity of further CPMAS processing is in question as may be the case in faulted CPMAS related equipments. The required actions for operator interface are shown in Figure 5-39.

5.3.4.2 Operator Initiated Fault Isolation

A controller may need to initiate fault isolation in response to user notification. It is anticipated that automatic fault detection/isolation will be responsive to nearly all faults in the digital system before a user is able to inform a controller of the same problem. However, a method will be provided to include user inputs to the fault analysis problem, particularly in cases where VF channels and subchannels are effected. The actions in response to a request for operator initiated fault isolation are shown in Figure 5-40.

5.3.4.3 Inter-Nodal Fault Isolation

The need for inter-nodal fault isolation occurs when a jump address in conjunction with the system connectivity data indicate that fault analysis must be directed outside of a nodal area. When this condition occurs, the fault isolation algorithm will carry out procedures for inter-nodal fault isolation as shown in Figure 5-41. The process at a node consists of informing the sector control station and awaiting supplementary data and/or commands to furnish data.

5.3.4.4 Actions On Unresolved Signatures

When the fault isolation algorithm is unable to find a fault signature in the equipment fault signature vocabulary an unresolved fault condition must be declared (see Figures 5-26 & 5-42). A controller will have to

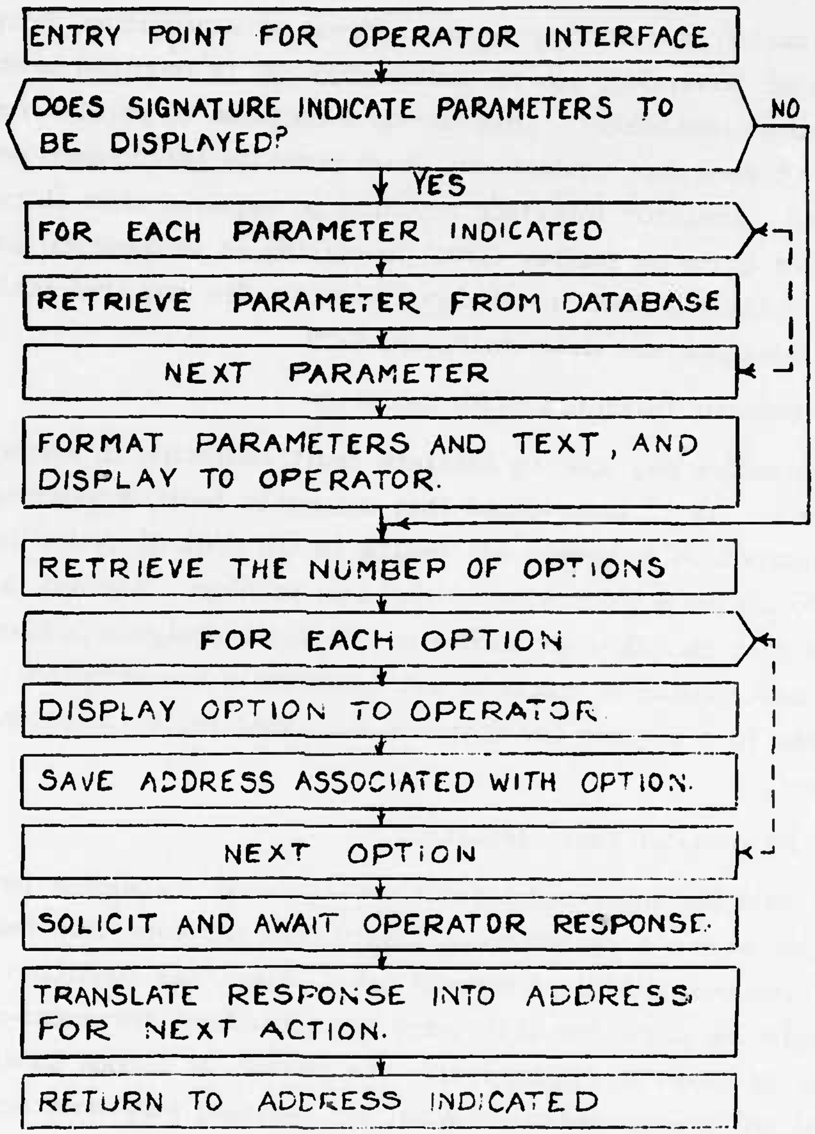


FIGURE 5-39. ACTIONS FOR OPERATOR INTERFACE

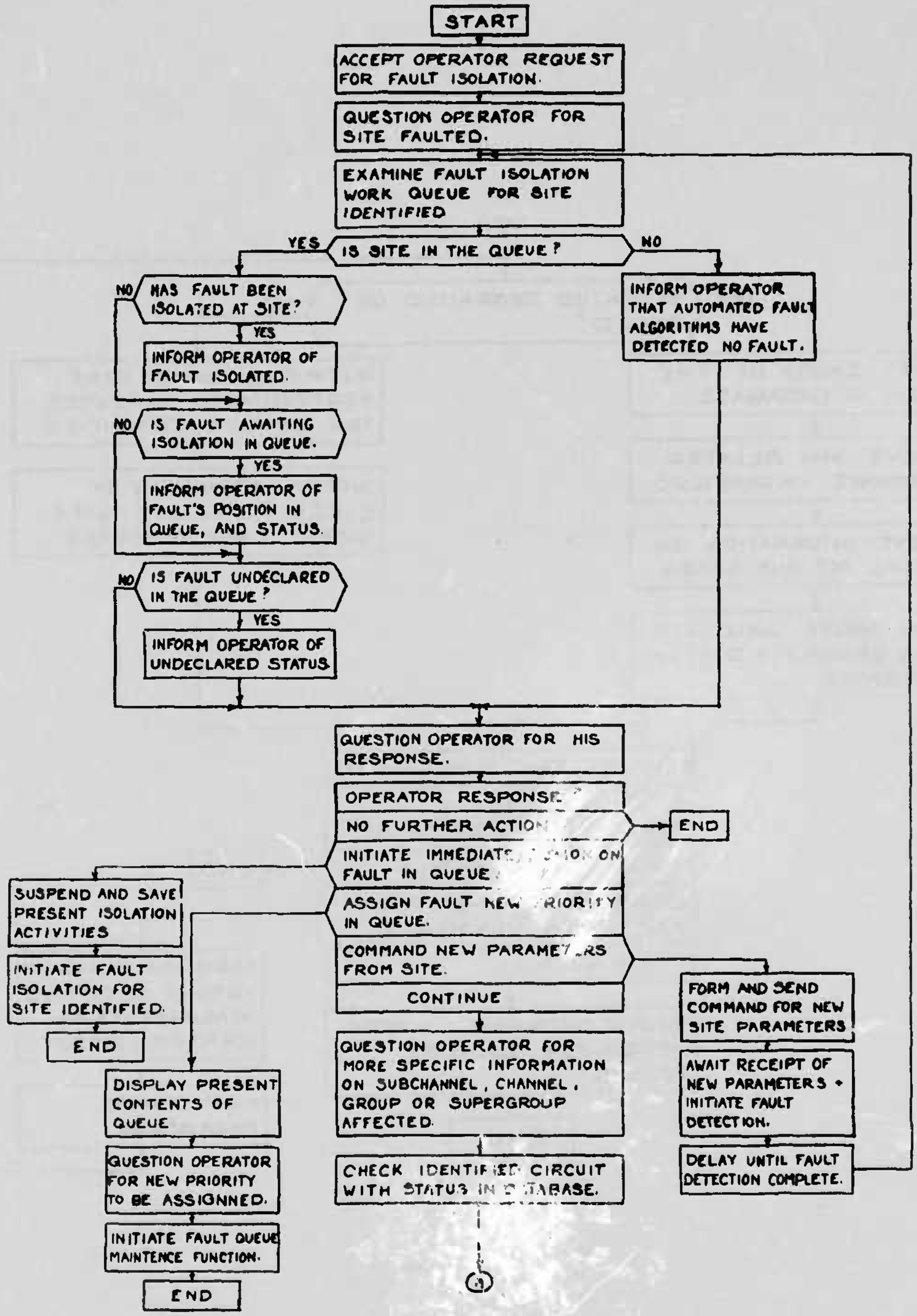


FIGURE 5-40. ACTIONS ON OPERATOR INITIATED FAULT ISOLATION
PAGE 1

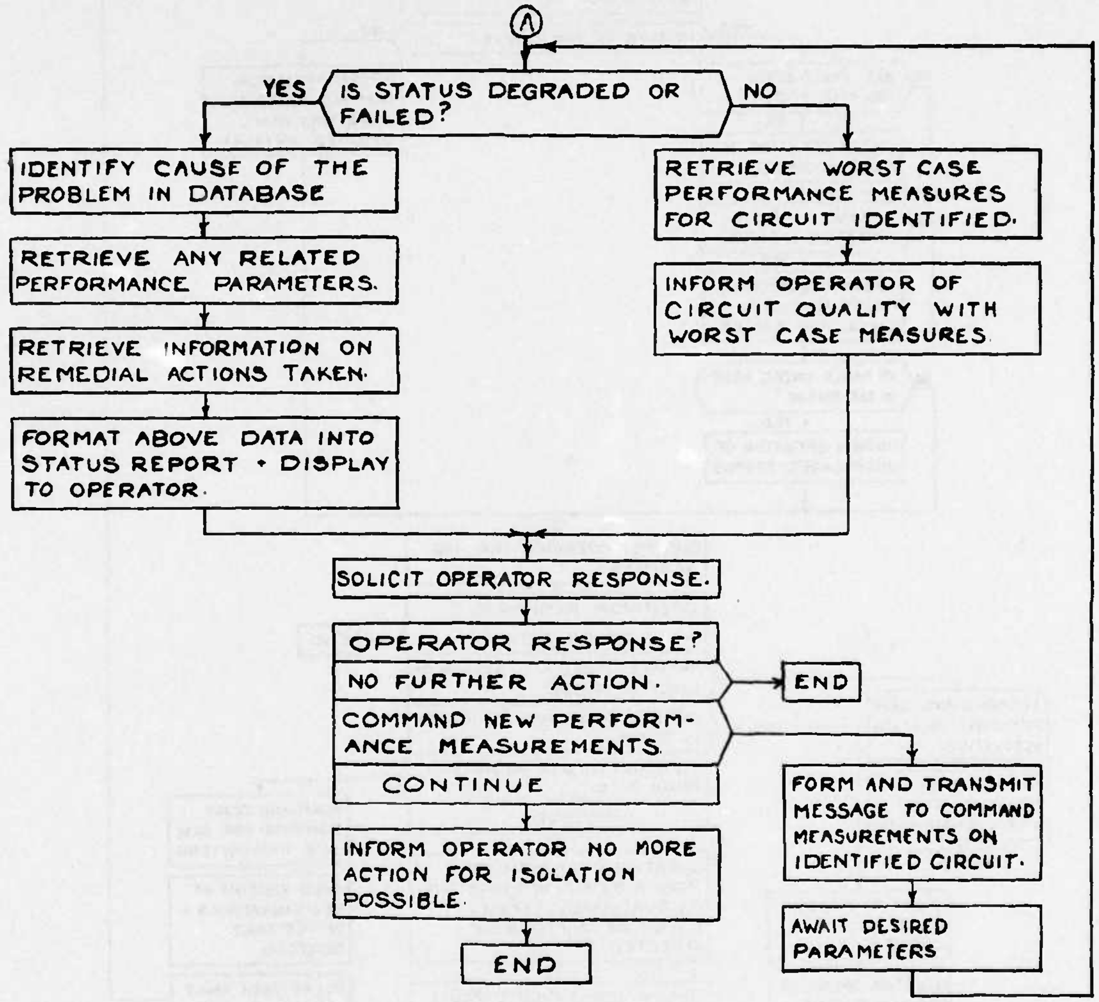


FIGURE 5-40. ACTIONS ON OPERATOR INITIATED FAULT ISOLATION PAGE 2

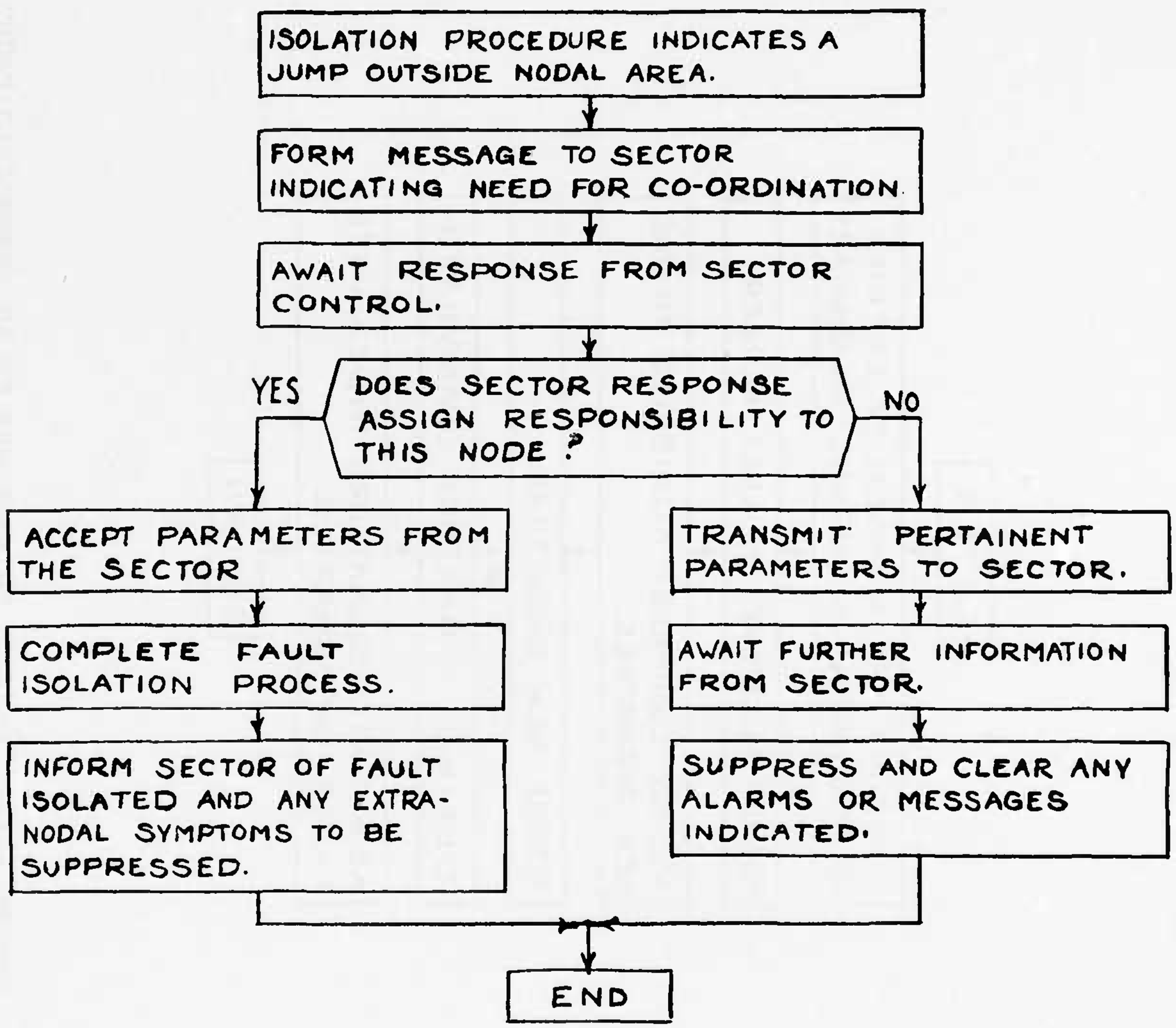


FIGURE 5-41.
SEQUENCE OF ACTIONS CORRESPONDING INTER-NODAL FAULT ISOLATION

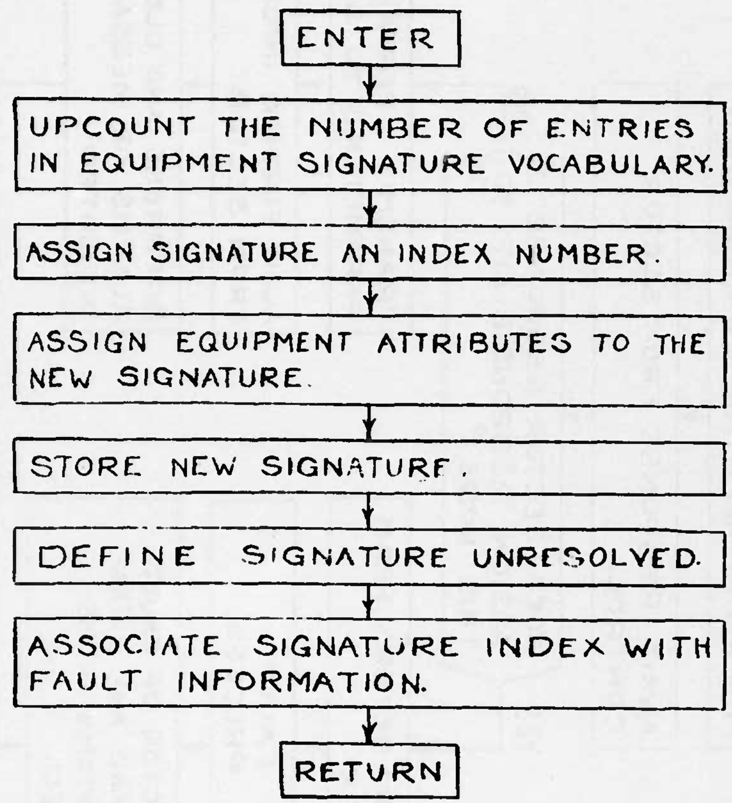


FIGURE 5-42. ACTIONS IN RESPONSE TO AN UNRESOLVED FAULT

utilize the nodal parameter database in order to manually resolve the fault. When the alarms causing the unresolved signature are identified with a cause, the operator may desire to augment the equipment signature vocabulary with this previously undefined signature. This requires operator inter-action with the nodal processor for supervised learning. An approach to signature learning is shown in Figure 5-43.

5.3.5 Fault Isolation Examples

Three examples of fault analysis actions are given below. The purpose is to illustrate how the fault detection/isolation algorithms work for a simple fault, and two sympathetically alarmed faults.

5.3.5.1 Example 1 - Figure 5-44

It is assumed that an RF power amplifier in one of the redundant transmitters for an AN/FRC 163 radio set has failed. It is assumed that alarm detection internal to the radio has detected the failure and switches to the standby unit without causing significant loss of transmission, as indicated by radio specifications.

The radio produces a transmitter power alarm for the A unit and a transmitter failure alarm for redundant unit A. No other alarms occur either at this site or at other sites.

The presence of alarms in the radio is detected by the CPMAS equipment, and transmission of the alarm data to the node is enabled. At the node, the fault detection algorithm (see figure 5-20) detects the incoming data and performs fault severity assessment for the received alarms as shown in Figure 5-22.

Assuming a weight of 10 for an amber alarm condition in an equipment, the total severity assessment for the faulted site will be 10. Assume the faulted site is located on an SCBS telemetry route labeled as #10 and is designated as site #9. If the fault is detected at 20:45:10 GMT, then the fault message formed will be as shown below.

10/09/0010/20:45:10

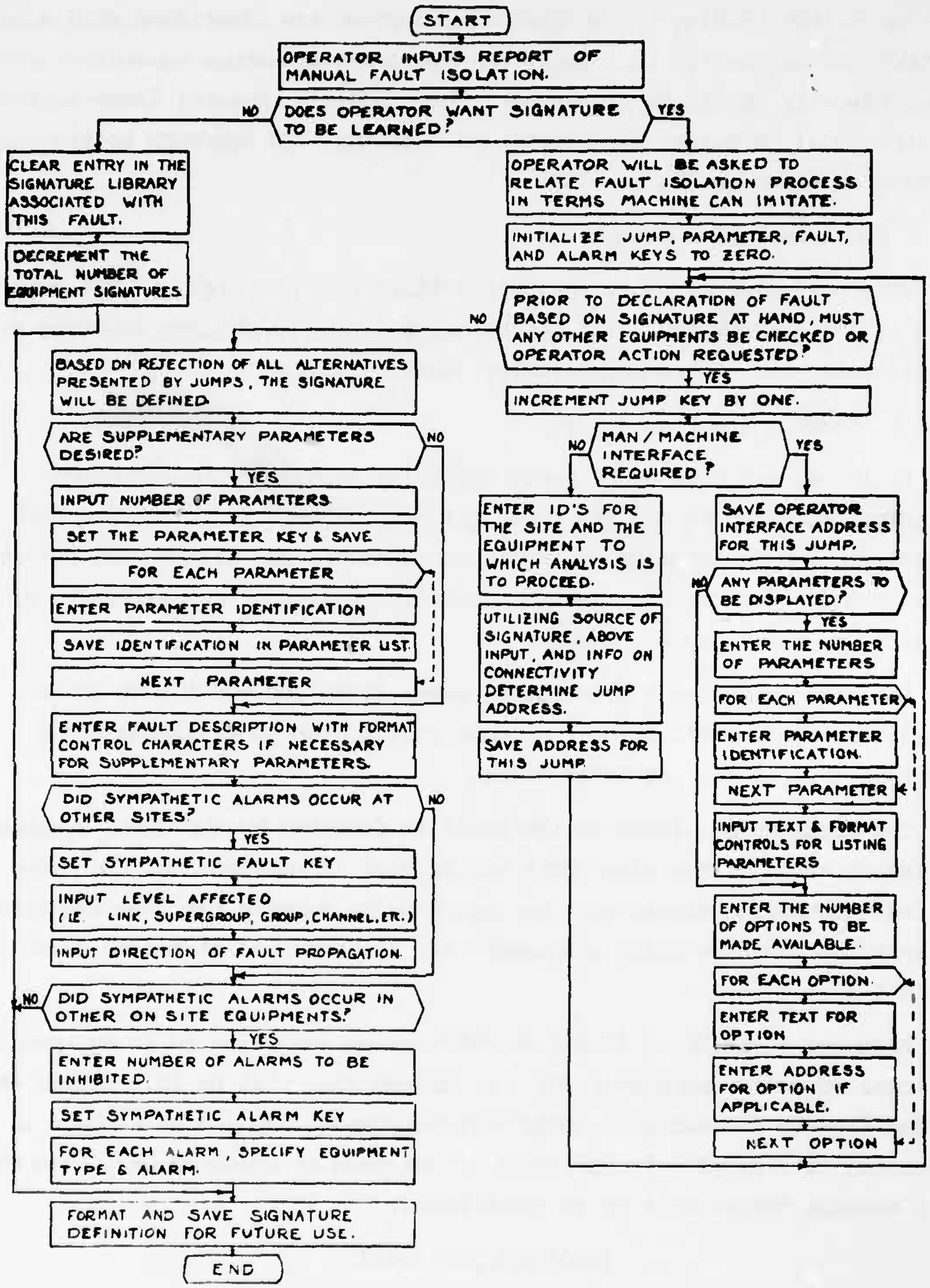


FIGURE 5-43.
ACTION IN RESPONSE TO RESOLUTION OF A PREVIOUSLY UNRESOLVED FAULT

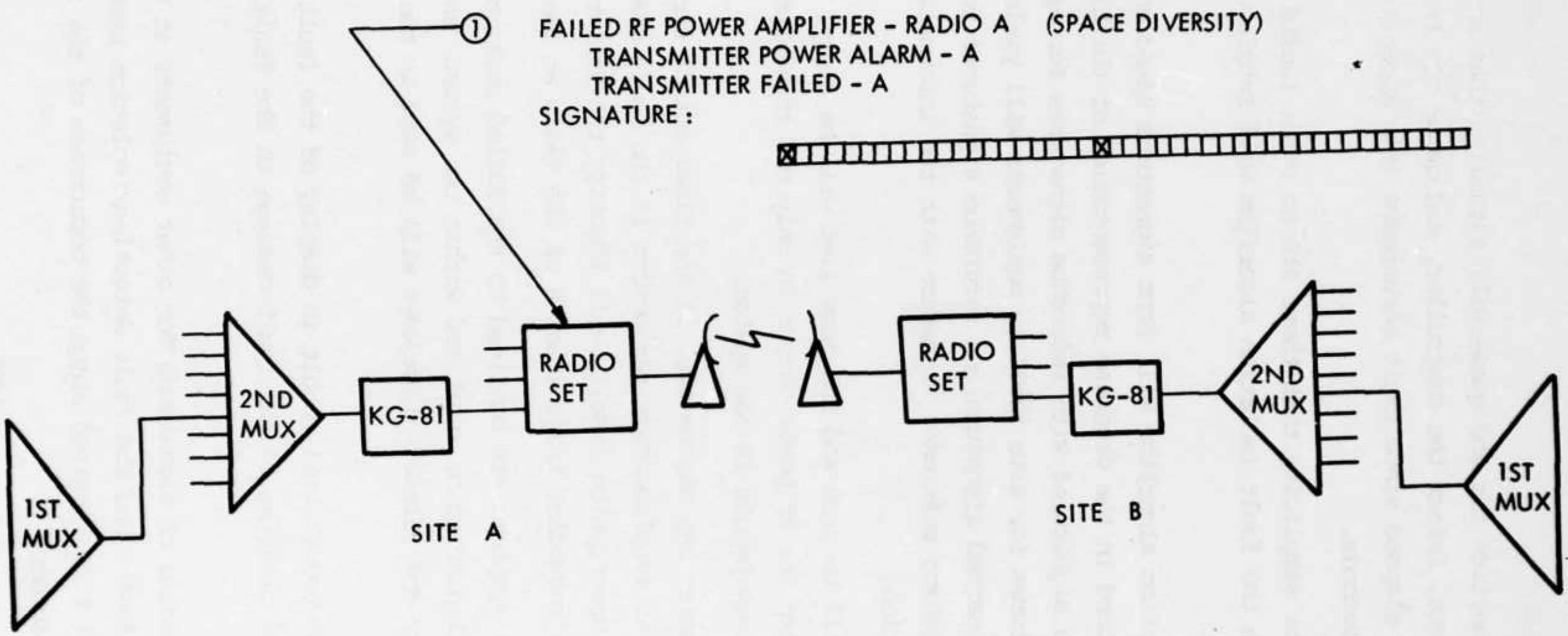


FIGURE 5-44. FAULT ISOLATION/DETECTION EXAMPLE

The message input function for the queue will establish that an amber alarm condition exists, inform the controller, and queue the fault message. An estimate of time elapsed since fault occurrence (see Appendix E) is approximately 4.58 seconds.

If we assume for simplicity that there are no other faults present in the nodal area, then the fault isolation algorithm will retrieve the fault message immediately.

The fault isolation algorithm will form signatures based on the states of binary alarms stored in the database representation of the alarmed site, and compare observed signatures with reference signatures for each equipment. Inspection of signatures for site facility equipments will yield no faults. Comparison of the observed signature and reference signatures for the radio will result in a matching reference signature with the information given below in its definition.

The jump key will be zero and the jump list will be empty, since the occurrence of an alarm for RF power output in only one transmitter will not be related to other equipments in the system.

The fault parameter key may be two, if the final output current and voltage are desired as supplementary parameters in the fault description message. The fault description itself, will identify the failure of an RF output section in redundant transmitter A of the radio at the alarmed site.

Since the fault symptoms are confined to the failed unit, no other faults or alarms will have to be inhibited within the system, and both the sympathetic fault key and related alarm keys will be zero in the signature definition.

The isolation procedure will result in display of the fault description to the controller and clearing of the fault message in the fault isolation work queue.

Continued processing of signatures for other equipments at the site will yield no other faults and the fault detection/isolation process will terminate. The total time required since the occurrence of the fault is approximately 4.63 seconds.

5.3.5.2 Example 2 - Figure 5-45

It is assumed here that a circuit failure in the 1st level multiplexer has caused loss of output from the multiplexer section.

If BITE in the 1st level multiplexer operates well, a circuit failure will be immediately detected and alarmed. Following lack of transitions for 100 ms. in the output of the 1st level multiplexer, a loss of output will be alarmed in the multiplexer. At the same or nearly the same time the 2nd level multiplexer connected to the failed unit will be alarmed for loss of low speed input for both redundant units. No alarms should occur in any other units on site.

Not shown, but possible, is the situation where the missing digroup passes through more 2nd level multiplexers (as at a branching repeater station) before reaching its terminal point. Each 2nd level multiplexer in the circuit will experience redundant loss of port alarms.

Finally when the digroup reaches its terminal point, the 2nd level multiplexer will be alarmed for loss of low speed output on both redundant multiplexers. The connected 1st level multiplexer will also be alarmed for loss of high speed input.

In another 200 to 400 milli-seconds both near and far end 1st level multiplexers will have a carrier group alarm. It is at this point, barring the occurrence of more independent faults, that the alarm characterization of the fault will be complete.

A number of complicating factors could be introduced at this time. We could assume that the fault symptoms cross nodal or sector boundaries and the fault symptoms cross nodal or sector boundaries and the fault isolation would have to be co-ordinated and data passed at higher system levels. The point of this example is to determine how well fault isolation algorithms functions, so to simplify the example without compromising the purpose we will assume that all actions take place within a nodal area.

Assume that all data related to faulted sites arrives at the node at the same time, and that for case 1 the location of the fault, site A, is nearest the node and in case 2 that the sympathetically faulted site, site B, is nearest the node.

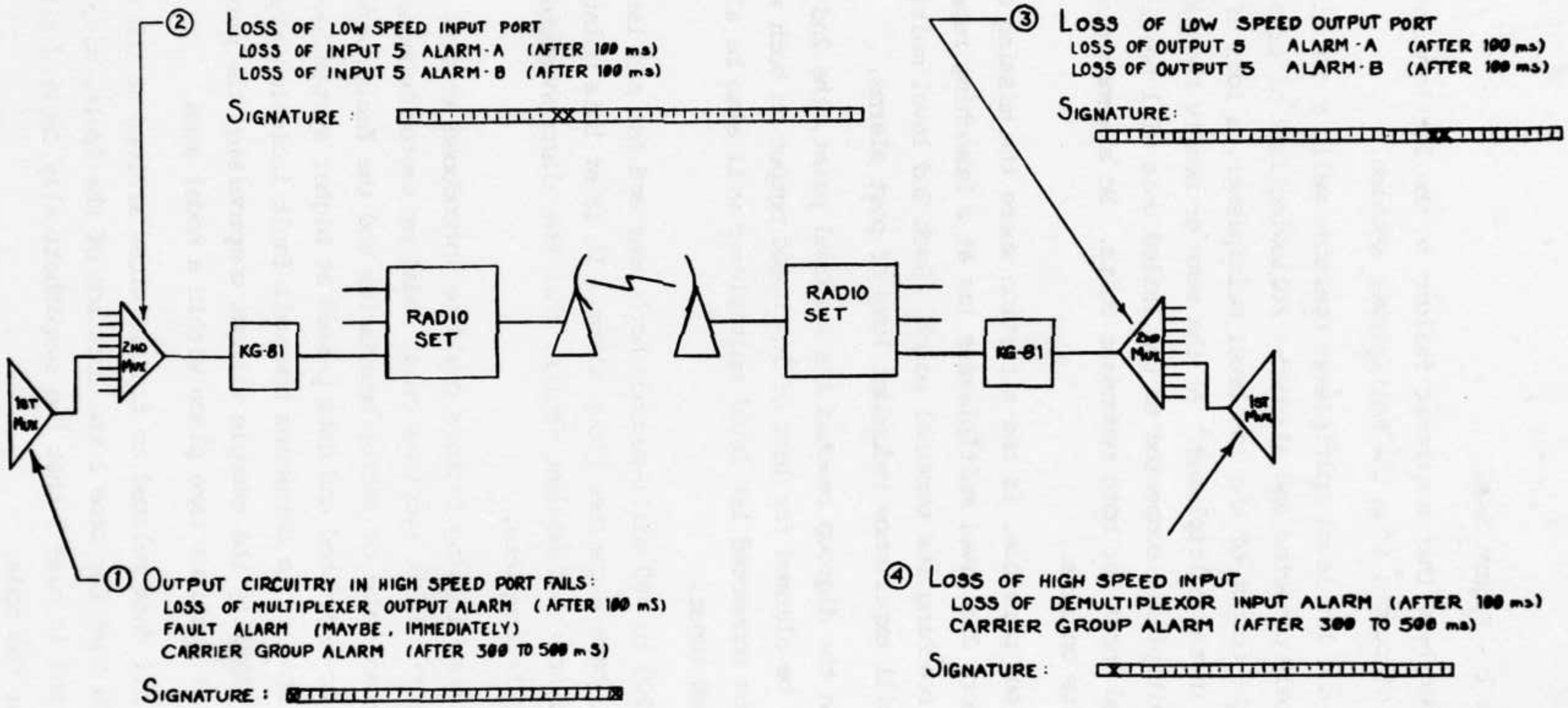


FIGURE 5-45. FAULT WITH SYMPATHETIC ALARMS

The alarms will be initially detected by the CPMAS equipments at the sites and sent to the node over the telemetry channel. The nodal fault detection algorithm will detect the incoming data and assess the severity of the site alarms. Utilizing the algorithm illustrated in Figure 5-22, assume the weights for alarms are as indicated below.

Red Alarms = 1000
Amber Alarms = 10

The alarm severity assessment at site A,

1st Multiplexer:	1000
2nd Multiplexer:	1000
Total:	2000

The alarm severity assessment at site B,

1st Multiplexer:	1000
2nd Multiplexer:	1000
Total:	2000

Assume that we are speaking of an SCBS telemetry route labeled as #10 with the site nearest the node labeled #9 and the site farther from the node being site #7. Assume for the purpose of illustration that all faults were first detected at the node at 14:20:58 GMT. Then for case 1 the fault messages would be;

10/09/2000/14:20:58 (site A)
10/07/2000/14:20:58 (site B)

For case 2 the fault messages would be;

10/09/2000/14:20:58 (site B)
10/07/2000/14:20:58 (site A)

Assume that the fault message input function of the fault isolation work queue does not require multiple reception of fault messages to declare a fault. Both faults will be declared red alarms and queued to the fault isolation work queue. The queue would appear as below for cases 1 and 2 respectively;

Queue (case 1)

/6/10/09/2000/14:21:00/
/6/10/07/2000/14:21:00/

Queue (case 2)

/6/10/09/2000/14:21:00/
/6/10/07/2000/14:21:00/

The controller will be informed of red alarms at sites A and B in either case. The time elapsed since fault occurrence at this point being about 3.08 seconds.

At this point the analysis for the two cases differs to some degree. So we will examine first case 1 and then case 2.

Case 1

The highest priority fault message is retrieved from the fault isolation work queue. This is the message indicating alarms at site A. The algorithm (see Figure 5-25) procedes to check equipments at the site for faults, taking no actions until the 2nd level multiplexer is encountered. The signature for the second level multiplexer, see Figure 5-45, indicates the presence of a fault. This signature is compared with reference signatures for a 2nd level multiplexer in an eight input digroup configuration. The observed signature will find a corresponding reference signature which should have the following information in its definition.

Since the alarms present are related to a particular input port, a jump to the source of the digroup input must be made. If only a summary port alarm was provided, then the signature could be related to alarms on any one of eight ports and at least eight jumps would have to be provided. If isolation to a particular port was to be insured, 16 jumps would be indicated.

It is for this reason that individual port alarms are recommended. These alarms will eliminate the uncertainty with respect to the particular faulted port inherent in the summary alarm. The number of jumps required if individual port alarms are provided will be 1 versus 8 or 16 for the summary alarm.

Additional parameters are not indicated and the parameter key will be zero and the parameter list empty.

If inspection of the 1st level multiplexer inputting the digroup to the alarmed 2nd level multiplexer yields no faults, then the conclusion to be reached is that the failure has occurred between the output of the 1st level multiplexer and the input to the 2nd level multiplexer. This failure could be in the interconnecting cables or driving circuits. There is an additional possibility, and that is that in the period of time required to do a scan, independent failures occurred in the two redundant input circuits for the multiplexer. The probability of this event based on a mean time between failures (MTBF) of 1600 hours and an interval of 1 second (highly exaggerated for purposes of illustration) is about 3 x esp(-14), i.e., highly unlikely.

If the conclusion reached indicates the fault isolated is directly related to the signature at hand, then all sites at which the faulted digroup is broken out of the super-group will experience red alarms from losses of input or output ports on 2nd level multiplexers. These alarms are sympathetic and will generate false alarm messages for each site. All these messages should be cleared in the fault isolation work queue, so that processing is not expended where no faults exist.

It should be noted again, that information on the particular port failed versus a summary alarm will be beneficial, reducing the number of fault messages to be suppressed by a factor of about 8. In addition suppression of alarm and fault processing at non-faulted sites is superfluous.

Since the fault is related to an input port, no further alarms should be generated at site, and the related alarm key will be zero and the related alarm list will be empty.

The information given above summarizes the content or information contained in the fault signature definition. The following paragraphs illustrate how this information is utilized.

The jump key will indicate the need to inspect the source of the digroup input to the 2nd level multiplexer, and the alarmed 1st level multiplexer will be inspected.

The signature definition for the 1st level multiplexer will convey the following information, and in this case the final actions in the fault analysis.

Since the alarms indicate a failure on the output bit stream, in addition to a BITE fault detected, no jumps will be required. The jump key will be zero and the jump list will be empty.

The parameter key will be zero and the parameter list will be zero.

The fault description will indicate a loss of high speed output from a 1st level multiplexer and this will be formatted together with site data and equipment data to specify the location of the fault. Information on the affected digroup will also be used to detemine circuit priority information, if need be.

The sympathetic fault key will be one and the sympathetic fault list will direct the algorithm to clear all faults in sites where this specific digroup is broken out, i.e., at site B in this case.

The related alarm key will be two, and the list will direct the algorithms to suppress sympathetic alarms in the redundant summary alarms in the connected 2nd level multiplexer.

This concludes the fault isolation process for case 1.

Case 2

The highest priority fault is retrieved from the queue. In this case since site B is closer to the node, its fault message has the greater priority, and fault analysis begins at the site. The fault isolation algorithms examine facility and equipment alarms finding no faults until the 2nd level multiplexer is encountered. The observed signature is then compared with reference signatures for a second level multiplexer with eight output digroups. The signature matched with the fault condition, see Figure 29, should contain the following information.

Since the alarms comprising the signature are related to an output port and no other alarms have been found in previous analysis of the site, the jump key should indicate two jumps. The first jump address will direct

analysis to the first point upstream from the node where a 2nd level multiplexer associated with the same super-group was encountered. The second address will direct fault algorithms to an operator interaction, to instruct the operator to switch redundant multiplexers on the previously checked 2nd level multiplexer, in order to check for unalarmed failures in the on-line equipment.

Should both jumps fail to detect any faults, then the fault related to the signature will be defined. In this case, no supplementary parameters are needed, i.e., the parameter key will be zero and the parameter list will be empty.

The fault description will identify the simultaneous failure of low speed output ports on redundant elements in the 2nd level multiplexer.

Sympathetic fault messages will be generated at any sites which the digroups are broken out of or into the supergroup between the node and the failed multiplexer. These messages should be cleared in the fault isolation work queue. A fault key of one giving the address of the digroup effected should be given.

Again note that although only one port is actually faulted, the uncertainty introduced by summary alarming of the ports would cause an eightfold increase in addresses and processing.

Related alarms on site will occur in all equipments associated with the faulted digroup. If we did not know specifically which digroup, then all alarms associated with all eight digroups would have to be inhibited on site.

The information contained above will result in the following actions taken by the fault analysis. The algorithm will make the first jump indicated to the second level multiplexer at site A. Examination of the signature for the 2nd level multiplexer will detect the faulted condition, and fault analysis will proceed as in the case previously examined. The worst case total time to detect and isolate in this case is about 3.12 seconds.

5.3.5.3 Example 3 - Figure 5-46

In this example it is assumed that a failure occurs in a KG-81 trunk encryption device located at site B. The failure is assumed to be in the decryption portion, and the BITE detects the failure. Following the failure a number of alarms occur in the nodal area shown in Figure 5-46.

At site B the TED indicated is alarmed for summary alarm. The 2nd level multiplexer connected to the plain text output from the failed TED is alarmed for loss of MBS data/timing in the loss of all digroup outputs on both redundant units approximately 100 ms. after the occurrence of the fault. The other 2nd level multiplexers at the repeater station are alarmed for loss of digroup inputs on both redundant units.

At sites A and C the 2nd level multiplexers are alarmed for loss of digroup outputs on the effected digroups in both redundant units. The 1st level multiplexers at each site connected to the missing digroups are alarmed for loss of input and carrier group alarm. If the 1st level multiplexers have digital outputs on the channel side, it is assumed that loss of these digital channels will be alarmed also.

After approximately 500 ms. all the alarms indicated will have been generated on site, and each site will enable transmission of the alarm changes to the node. At the node, the alarms will be detected by the fault detection algorithms and a severity assessment of the alarms at sites A, B, and C will be made.

For purposes of the example, it will be assumed that there are no digital channels present at the outputs of the alarmed 1st level multiplexers. Assume that the weights for assessing the severity of site alarms are as shown below.

Red Alarms = 1000

Amber Alarms = 10

The severity assessment at site A will be;

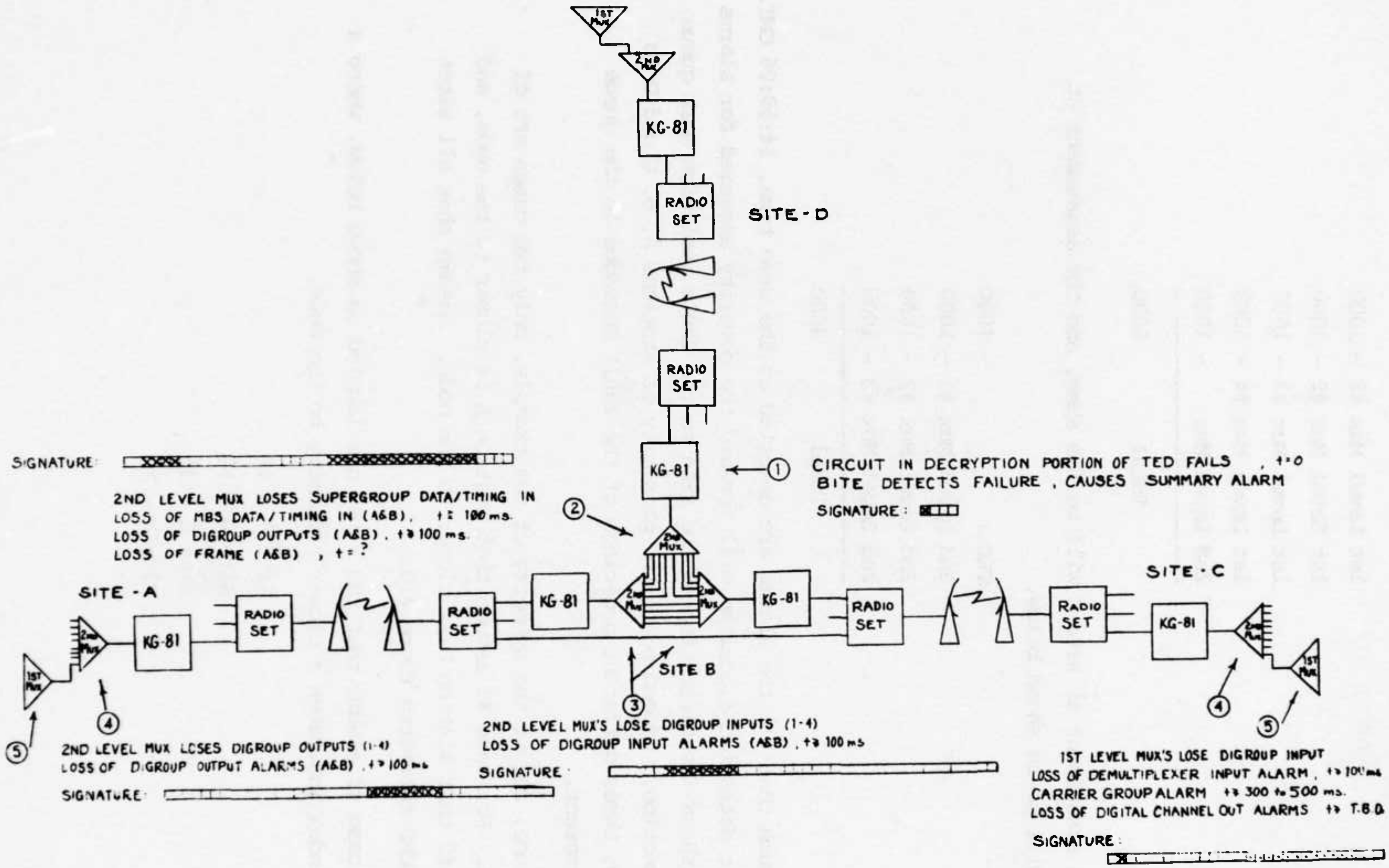


FIGURE 5-46. FAULT ANALYSIS EXAMPLE 3

1st Level Mux #1	- 1000
1st Level Mux #2	- 1000
1st Level Mux #3	- 1000
1st Level Mux #4	- 1000
2nd Level Mux	- 1000
Total	5000

The assessment at site C will be the same, and the assessment at site B will be as shown below.

TED	- 1000
2nd Level Mux #1	- 1000
2nd Level Mux #2	- 1000
2nd Level Mux #3	- 1000
Total	4000

Assume that all the alarms are detected at the same time, 14:59:06 GMT. The fault detection algorithm will forward the severity assessed for alarms along with an identification of the site to the fault isolation work queue input function. Depending on the proximity of stations A, B, C and D to the node, three different orderings of the fault messages in the queue may be present.

Assume, due to the symmetry of the example, only two cases are of interest. For case #1 assume that station A is closer to the node, and in case #2 that station D is closer to the node. Assume that all sites are on SCBS telemetry route #10.

In case #1 assume that the sites are labeled as shown below, where a higher index indicates a closer proximity to the node.

Site A - #8
Site B - #7
Site C - #6
Site D - #5

For case #2 assume the following labeling of the sites.

Site A - #5
Site B - #7
Site C - #6
Site D - #8

The effect of the labeling the sites differently in the two cases is to cause a higher priority to be assigned to site A in case #1 and site D in case #2. In the actual system only one such ordering would exist. The time required to detect and assess the fault is approximately 7.6 seconds in this example.

For case #1 the fault isolation work queue will appear as below.

/6/10/08/5000/14:59:09/ (site A)
/6/10/07/4000/14:59:09/ (site B)
/6/10/06/5000/14:59:09/ (site C)

And in the #2 case the queue will be as shown below.

/6/10/07/4000/14:59:09/ (site B)
/6/10/06/5000/14:59:09/ (site C)
/6/10/05/5000/14:59:09/ (site A)

For case #1, the fault isolation algorithm retrieves the fault message identifying site A as being alarmed. Using the nodal parameter database signatures are formed as each equipment at the site is checked. Signatures for the facility equipments, radio, and TED yield no faults. However, the signature for the 2nd level multiplexer does indicate a fault condition. The signature definition for the matching reference signature should contain the following information.

The jump key will be two. The first address will direct analysis to the next point upstream where the missing digroups are broken out. The second address will request operator interface to effect switching of the far end multiplexer, in case of an unalarmed failure.

Since no supplementary parameters would be required for the fault description, the parameter key will be zero and the list will be empty.

The fault description will describe failure of both redundant output circuit for each of the four missing digroup outputs. This is an unlikely event.

Sympathetic fault messages will be generated at any sites where the four lost digroups are broken out of the supergroup downstream from the faulted site. Therefore, the sympathetic fault key will be four, and the sympathetic fault list will list the digroups associated with the lost output ports.

The related alarm key will also be four. The alarm list will identify the four lost digroup outputs and any subsets of them for alarms at other equipments at the same site and downstream from the ports.

Utilization of the signature definition above will direct the analysis to the #1 2nd level multiplexer at site B. The fault signature for that piece of equipment will indicate a fault and the definition of the matching reference signature is given below.

The jump key will be four. The four jump addresses will identify the digroups associated with each of the lost multiplexer input digroup ports.

There will be no supplementary parameters required for a fault description and the parameter key will be zero and the parameter list will be empty.

The fault description, should jump locations fail to be alarmed, will describe the simultaneous loss of four lines supplying the multiplexer with the digroup inputs, or the simultaneous failure of four input circuits and their redundant elements. The last event is highly improbable.

The sympathetic fault key will be four, identifying downstream sites at which the failed digroups are broken out, for suppression of fault processing. No related alarm at the same site will be identified.

Using the definition above analysis will be directed to 2nd level multiplexer #2 at the same site, where the signature will indicate the presence of a fault. The signature for the equipment will indicate the following.

The jump key will be two indicating a check of the TED and the radio upstream from the multiplexer. No supplementary parameters will be requested.

The fault description, in lieu of faults at the two jump locations, will be simultaneous loss of MBS input circuits on redundant elements or a discontinuous connection on a cable patching the multiplexer to upstream devices.

The sympathetic fault key will be 1 identifying all sites downstream from faulted multiplexer where the supergroup is broken out for alarms.

The related alarm key will be 1. The alarm list will identify on site equipments downstream from the faulted multiplexer lost supergroup. Alarms occurring in these equipments will be suppressed so that no unneeded fault processing is performed.

Using the signature definition for multiplexer #2 at site B, analysis will be directed to the failed TED. The observed signature will indicate the presence of a fault at the KG-81, and the matched reference signature will have the following information.

No jumps will be specified. The jump key will be zero and the address list will be empty.

There will be no supplementary parameters called for in the fault description so that the supplementary parameter key will be zero and the parameter list will be empty.

The fault description will identify the fault as a failed trunk encryption device. Because of the few alarms provided on this device no more specific a fault description will be given.

The sympathetic fault key will be one and the supergroup passing through the TED will be given in the address for suppression of fault processing on other alarmed sites for which the supergroup or subsets of it are broken out.

The related alarm key will be one. The related alarm list will identify alarms occurring in equipments through which the faulted supergroup or subsets of it pass for suppression to prevent unnecessary fault analysis.

Using the signature definition above, the fault isolation algorithms will isolate the fault to the TED. Alarms on site in the 3 second level multiplexers will be inhibited and no fault processing will take place on those devices. Likewise the sympathetic fault key will cause fault processing at sites A and C to be inhibited. The operator will be given the fault description and the fault analysis for this fault will be complete.

In case #2 the fault isolation algorithm selects site B for fault isolation 1st. The fault isolation algorithms compares signatures for the facility equipments and the radios to the reference signatures for them and finds no faults. When the TED associated with 2nd level multiplexer #2 is checked, the signature indicates a fault and the fault analysis proceeds from this point as it did in the above example for the TED. The worst case time for fault isolation and detection in this example is approximately 7.78 seconds.

5.3.6 Recommendations

A number of recommendations follow from the CPMAS fault isolation/detection study. The techniques specified in section 5.3.2 and summarized in Figure 5-28 are recommended as the CPMAS fault analysis approach. In addition the following recommendations are made.

Individual port alarms for digroup inputs and outputs on the 2nd level multiplexers are recommended. Individual port alarms for digital channel inputs and outputs on the 1st level multiplexers are recommended. These recommendations are based on a need to specifically identify faulted digroups and digital channels. Without these alarms faults in interconnecting cables will not be readily identifiable.

Transmission of station alarms and parameters to the nodal processor is a prime concern. Fault isolation time is directly proportional to transmission time with all other aspects of fault isolation contributing an amount of time insignificant in comparison. Slow telemetry also implies fault isolation which cannot be made responsive to intermittent faults of short duration. Binary encoding of data used for fault isolation transmitted

via telemetry is recommended, as opposed to ASCII coding. In either case, the highest telemetry rate consistent with other system requirements and capabilities should be used.

Remote switching of redundant equipments to facilitate isolation of unalarmed failures in equipments should be offered as an operator initiated option. The alternative to remote switching is a situation where an uncertainty in fault location between two possibly remote stations could exist when unalarmed failures in equipments occur.

5.4 Telemetry

The telemetry network is an integral part of the nodal area CPMAS shown in Figure 5-47. The Wideband Digital CPMAS data at each of the stations of the nodal area is monitored by the station's Wideband Digital Monitoring Set (WDMS) and transmitted via the Communications Interface Set (CIS) and a Telemetry Channel to the Nodal Control Processing Subsystem (CPMAS-NCS). The Service Channel Multiplexer provides telemetry channel access as well as orderwire channels for Technical Control. The relationship of the telemetry channel within the nodal area CPMAS is simply shown in Figure 5-48. All communications between a station and nodal control is transmitted via its assigned telemetry channel.

Each telemetry channel must provide digital telemetry communications among the three major areas shown in Figure 5-49, the MAS elements including WDMS, Station Controller Position and Nodal Control. The effects of Telemetry and Telemetry Channel Bit Rate upon CPMAS performance is described in this section.

The basic Wideband Digital CPMAS telemetry functions are:

1. Transmit alarm, status and performance assessment data from the Wideband Digital Monitoring Set (WDMS) to Nodal Control via the CIS and Telemetry Channel.
2. Transmit alarm, status, control, reporting and display messages between nodal control and station control via the CIS and telemetry channel.

Section 5.4.1 analyzes the CPMAS data coding alternatives which influence the first telemetry function above. Section 5.4.2 analyzes the effect of Telemetry and CIS-Station Control interface channel rates upon nodal control display transmission times. Section 5.4.3 summarizes the Wideband Digital CPMAS Telemetry recommendations.

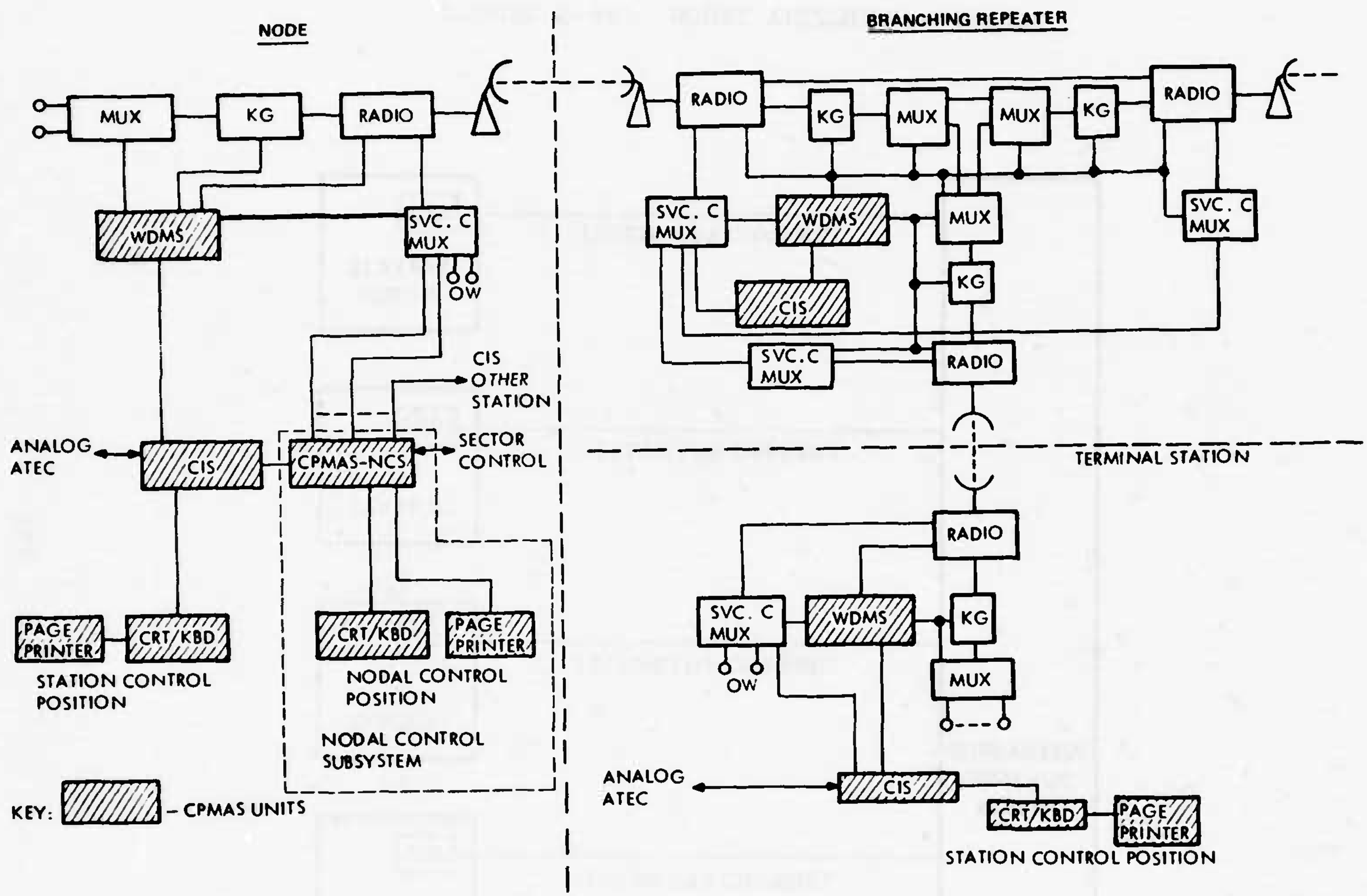


FIGURE 5-47. CPMAS SYSTEM BLOCK DIAGRAM

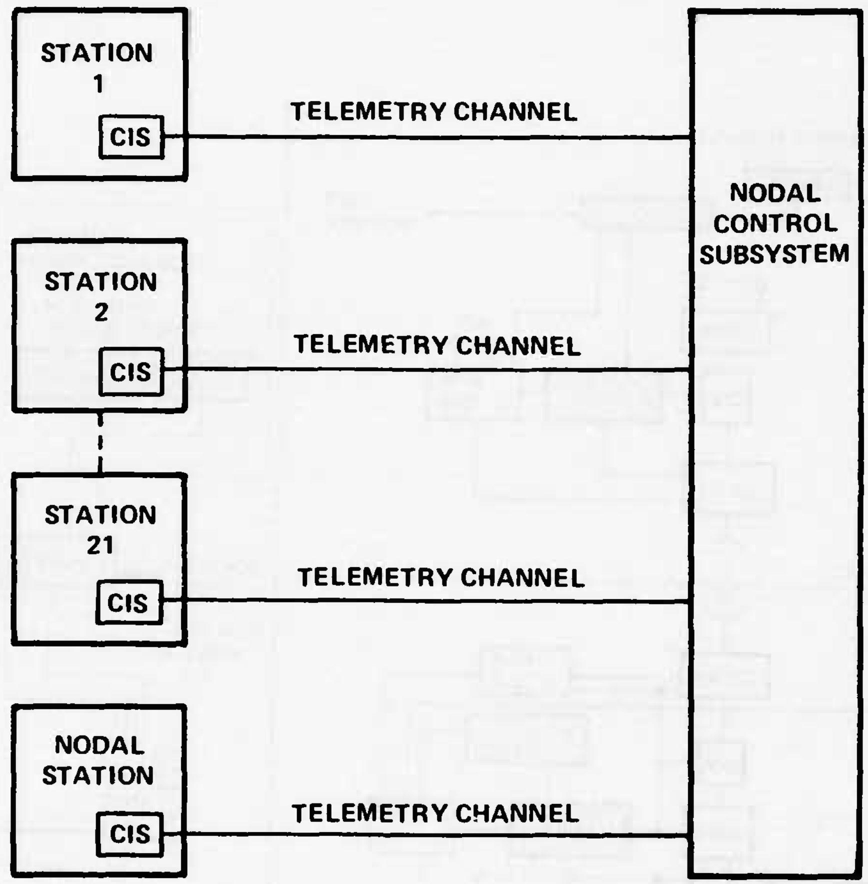


FIGURE 5-48. MODEL TELEMETRY NETWORK

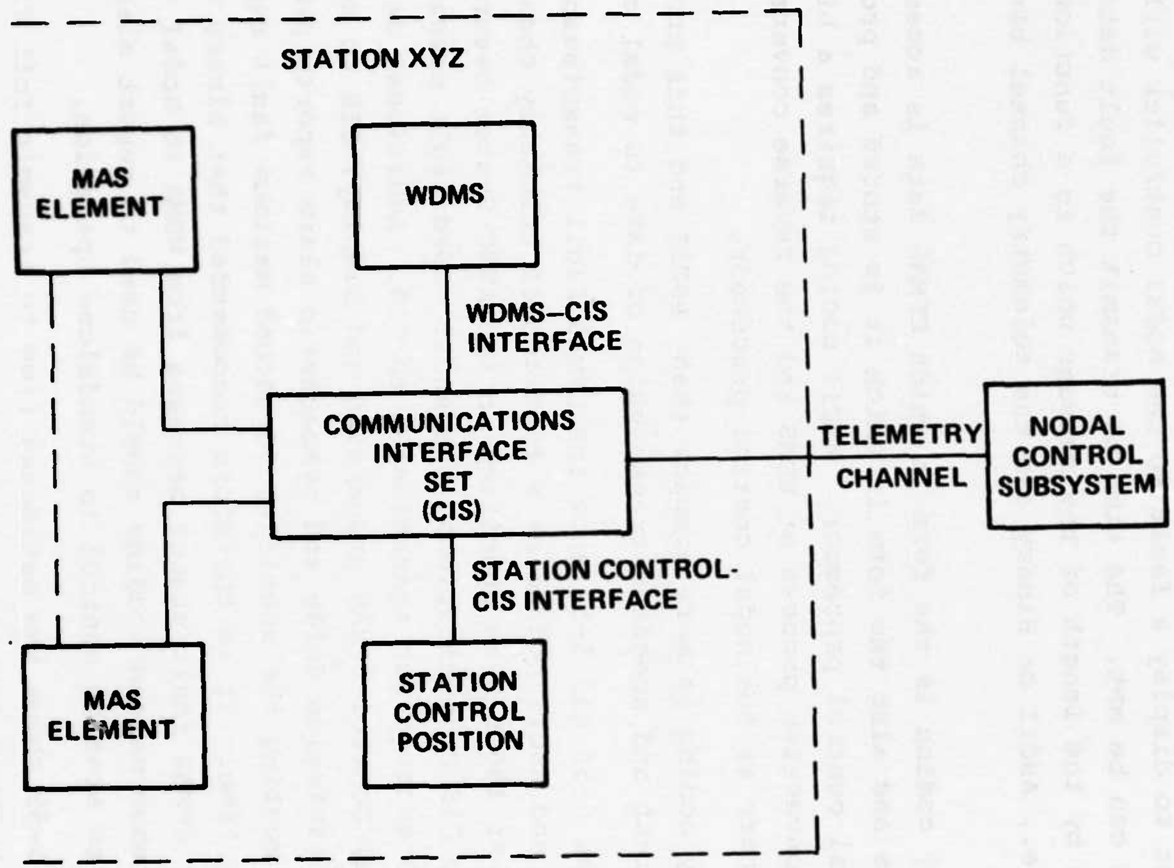


FIGURE 5-49. TELEMETRY COMMUNICATIONS

5.4.1 Wideband Digital CPMAS Data Coding Alternatives

The Wideband Digital CPMAS data at WDMS is communicated to Nodal Control (CPMAS-NCS) via the telemetry channel. The transmission time for this data must be sufficiently small so that when added to processing delays, the ATEC System Description requirement to display a fault to the nodal controller within 30 seconds can be met. The time to transmit the fault data is determined by the length of the message which is a function of coding, i.e., ASCII or Binary and the telemetry channel bit rate.

Binary coding is the form in which CPMAS data is accessed at the WDMS and also the form in which it is stored and processed in the nodal control processor. ASCII coding requires a binary to ASCII conversion process at WDMS and the reverse conversion back to binary at the nodal control processor.

Binary coding is more compact than ASCII and thus provides more efficient and speedier transmission of data to nodal control.

Figures 5-50 and 5-51 show the CPMAS fault transmission times for Binary and ASCII coding as a function of telemetry channel bit rate. At 150 B/S as specified in the ATEC System Description for WDMS to CIS Communications, the ASCII coded fault message requires 30 seconds for transmission to CIS. Additional delays due to Nodal Control CPMAS processing and display, CIS to Nodal Control transmission delay and sympathetic alarm reports prevent CPMAS from meeting the specified 30 second maximum fault reporting/display time. It is therefore recommended that binary coding be used for CPMAS fault/status messages from WDMS to Nodal Control. The same message coding should be used to report alarms and status to station control in Standalone operation.

Figure 5-52 shows the estimated time to transmit full Wideband Digital CPMAS data for the branching repeater in the Digital Transmission System model. To transmit the status of this single station using ASCII coding and 150 B/S WDMS-CIS channel rate

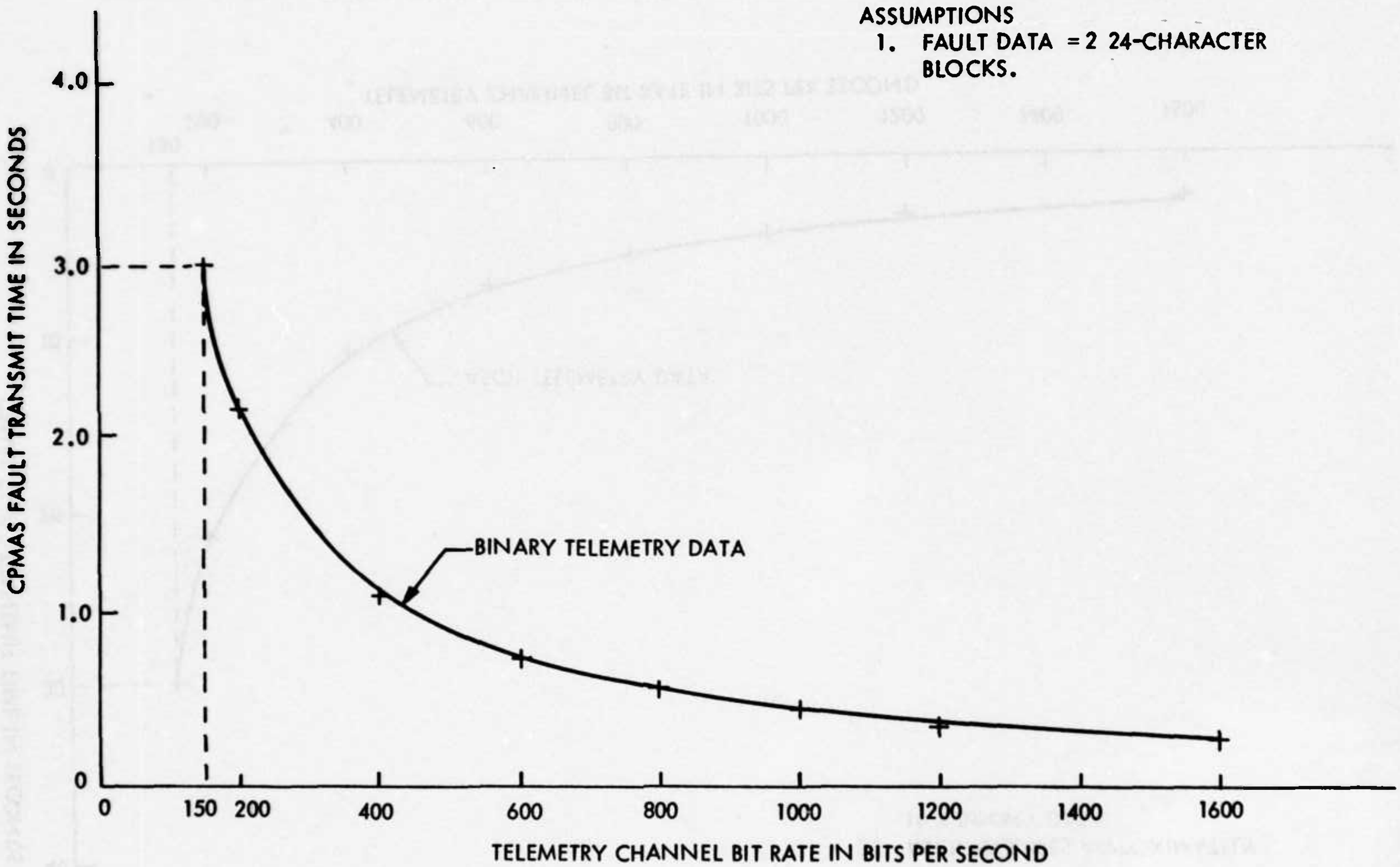


FIGURE 5-50. CPMAS FAULT TRANSMIT TIME VERSUS TELEMETRY CHANNEL BIT RATE

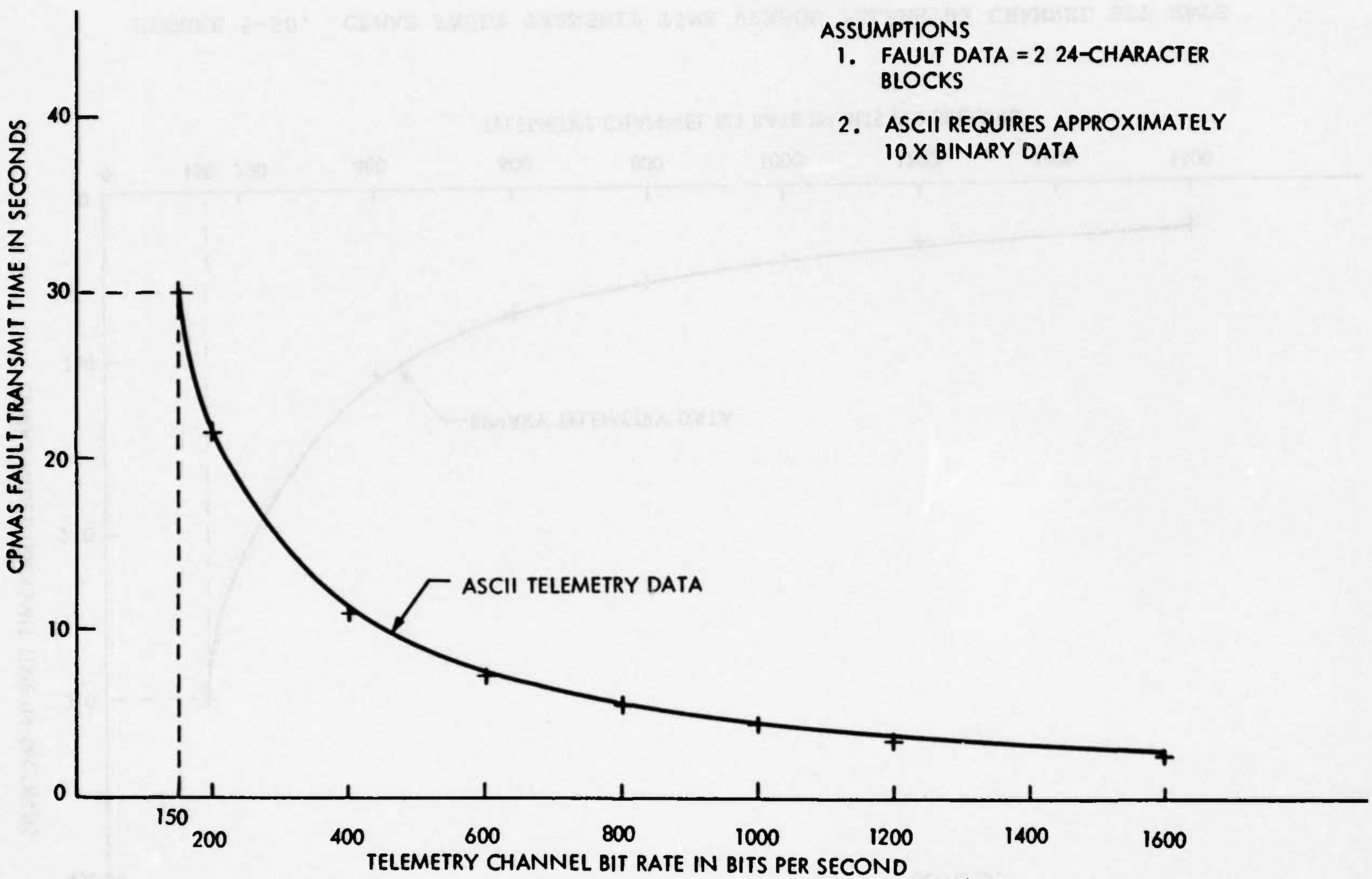


FIGURE 5-51. CPMAS FAULT TRANSMIT TIME VERSUS TELEMETRY CHANNEL BIT RATE

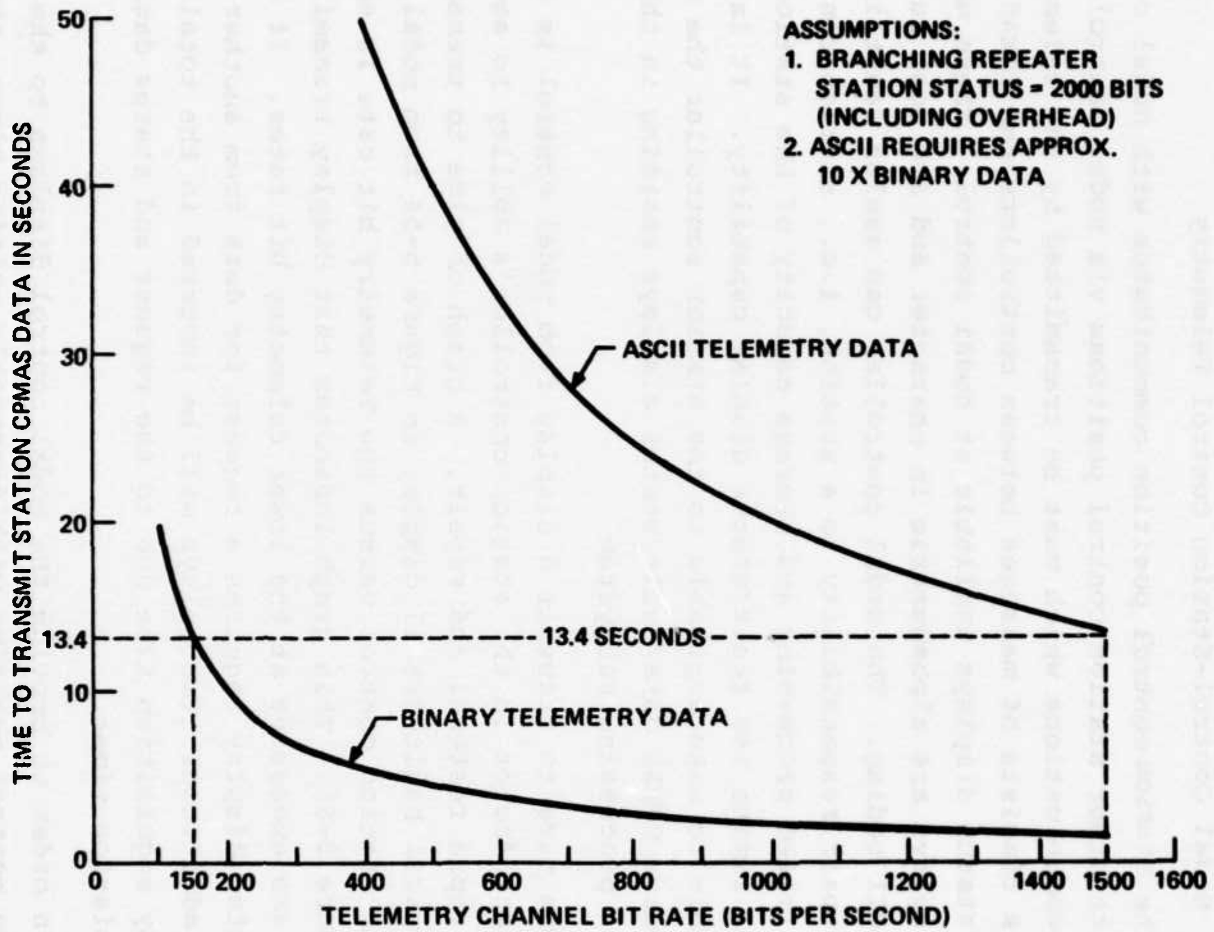


FIGURE 5-52. CPMAS DATA TRANSMIT TIME VERSUS TELEMETRY CHANNEL BIT RATE

would require more than two minutes while binary coding would provide transmission in the area of 10 to 20 seconds.

Figure 5-53 summarizes the general advantages and disadvantages of Binary and ASCII CPMAS message coding.

5.4.2 Nodal Control-Station Control Telemetry

The station control position communicates with nodal control and with other station control positions via nodal control. This communications which must be transmitted by the telemetry network consists of messages between controllers and CPMAS data/fault/status displays available at nodal control. These messages and displays are alphanumeric in character and are most suited to ASCII coding. The nodal controller can assign fault isolation/repair responsibility to a station, i.e., station controller. The limited processing and storage capacity of the station control limits its fault/status display capability. It is thus desirable to make available to the station controller the comprehensive CPMAS data/fault/status displays residing in the nodal control processing subsystem.

The time to transmit a display from nodal control is an important factor in the station controller's ability to accomplish rapid restoral and repair. A graph of time to transmit the typical Fault-Detail display in Figure 5-54 from nodal control to station control versus the Telemetry bit rate is shown in Figure 5-55. This graph indicates that display transmission times are excessive at the lower telemetry bit rates. If a requested display requires a request for data from another station, additional time delays will be incurred in the total display acquisition time due to the request and status data transmission times.

In order to provide the nodal control displays to the station control position with acceptable waiting times, the nodal control to station control communication channel rate should be 2400 B/S. The display example in Figure 5-54 can be completely

CODING ALTERNATIVES	ADVANTAGES	DISADVANTAGES
BINARY	• BEST SUITED TO NCS PROCESSOR • EFFICIENT INFORMATION TRANSFER	• REQUIRES PROCESSING FOR STATION CONTROL DISPLAY
ASCII	• BEST SUITED FOR STATION CONTROL DISPLAY	• INEFFICIENT INFORMATION TRANSFER • REQUIRES RECONVERSION TO BINARY AT NCS PROCESSOR

FIGURE 5-53. TELEMETRY DATA CODING

```
                          CHARACTER NUMBER

  LINE   :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
 NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
---------+--------------------------------------------------------------------------------+
       1 :FAULT-GP-R/FAULT-GP-R/                                           17/1040 FEB 77:
       2 :                                                                         48/1040:
       3 :                                                                                :
       4 :                              FAULT  DETAIL                                     :
       5 :                                                                                :
       6 :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--       TIME      :
       7 :  GP       R  34JKB8   ABC M0298 02 08        1ST-MUX,GP,TX            048/1013:
       8 :                                                                                :
       9 :           EQUIPMENT        EQUIP.TYPE    ALARM     STATUS  CONTROL             :
      10 :1ST-MUX ABC M0298 02 08        TD1192     GP,TX        ALM    ( )DET             :
      11 :2ND-MUX ABC M0298 02           TD1193     GP08,RCV     ALM    ( )DET             :
      12 :2ND-MUX GHI M0299 02           TD1193     GP08,TX      ALM    ( )DET             :
      13 :2ND-MUX GHI M0692 01           TD1193     GP01,RCV     ALM    ( )DET             :
      14 :2ND-MUX JKL M0692 01           TD1193     GP01,TX      ALM    ( )DET             :
      15 :1ST-MUX JKL M0692 01 01        TD1192     GP,RCV       ALM    ( )DET             :
      16 :                                                                                :
      17 :  PATH                                                                          :
      18 :     ABC-M0298-DEF-M0299-GHI-M0692-JKL    ( )DET                                 :
      19 :                                                                                :
      20 :  TRUNKS AFFECTED                                                               :
      21 :     34JKB8 ( )DET    31CY22 ( )DET                                              :
      22 :                                                                                :
      23 :  CIRCUITS AFFECTED                                                             :
      24 :     DUUC5ABT ( )DET    DUUK3NBC ( )DET                                         :
         +--------------------------------------------------------------------------------+
```

FIGURE 5-54. FAULT DETAIL DISPLAY

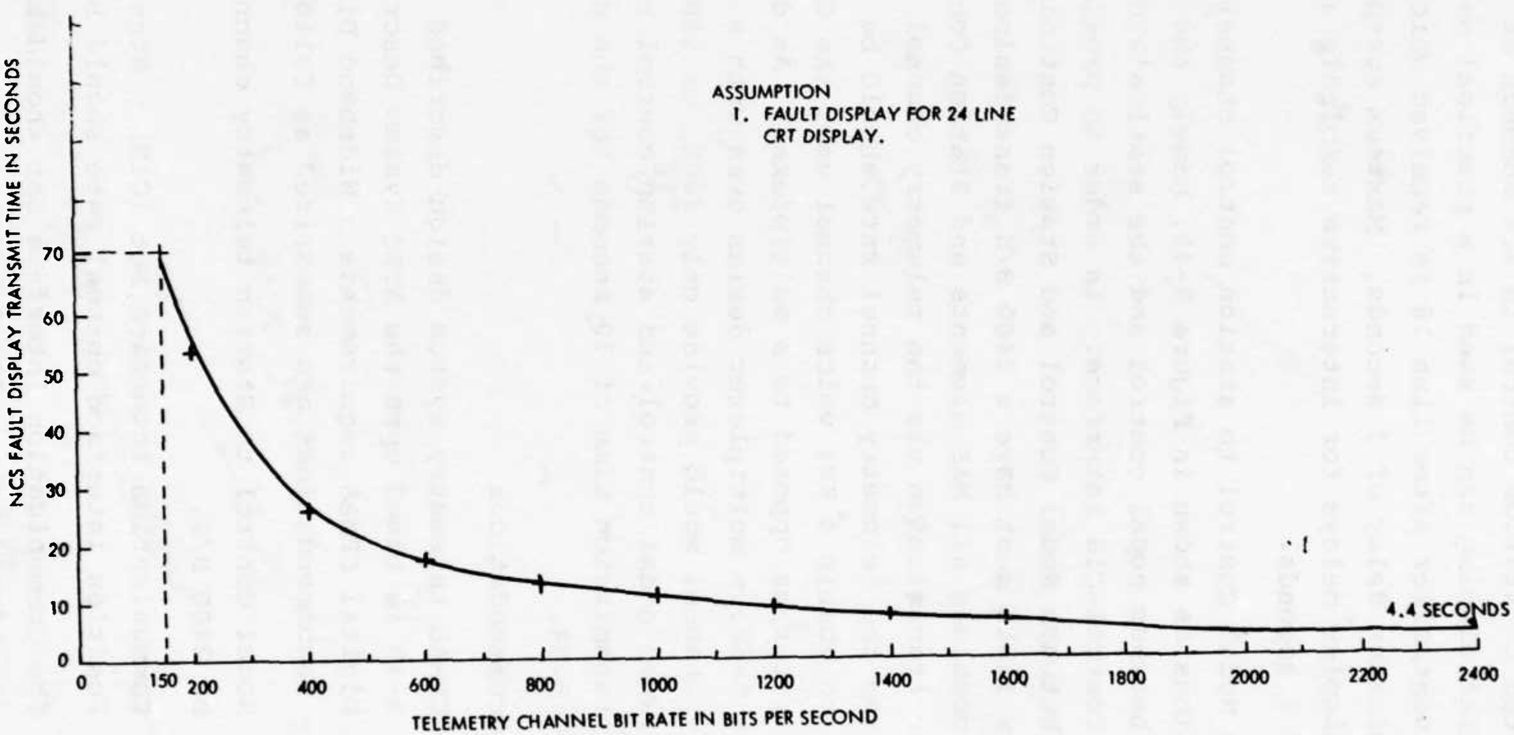


FIGURE 5-55. NCS FAULT DISPLAY TRANSMIT TIME VERSUS TELEMETRY CHANNEL BIT RATE

transmitted to station control in 4.4 seconds at 2400 B/S. The partial display can be used in a practical manner by the station controller after line 16 is received which represents a transmission delay of 3 seconds. Maximum acceptable human factor display delays for interactive terminals are in the order of 3 seconds.

The Nodal Control to station control channel consists of two sections as shown in Figure 5-49, namely the telemetry channel between nodal control and the station's CIS and the Station Control-CIS interface. In order to provide 2400 B/S service between Nodal Control and Station Control, both of these telemetry links must have a 2400 B/S transmission rate. Since the CIS combines all MAS elements and Station Control communications for transmission via the telemetry channel to nodal control and the telemetry channel rate should be limited to 2400 B/S to enable 4 KHz voice channel use, the CIS should be a concentrator as opposed to a multiplexer. As demonstrated in Figure 5-56, a multiplexer design even with a 2400 B/S telemetry channel would provide only $\frac{2400}{16}$ or 150 B/S communications between nodal control and station control resulting in a display transmission time of 70 seconds for the display example in Figure 5-54.

5.4.3 Recommendations

The CPMAS telemetry system design described in Figures 5-47, 5-48 and 5-49 is based upon the ATEC System Description and Wideband Digital CPMAS requirements. Wideband Digital CPMAS telemetry recommendations are summarized as follows:

1. Nodal Control to Station telemetry channel rate should be 2400 B/S.
2. Communication Interface Set (CIS) - Station Control Position interface channel rate should be 2400 B/S.
3. The Communication Interface Set should be a concentrator as opposed to a multiplexer.

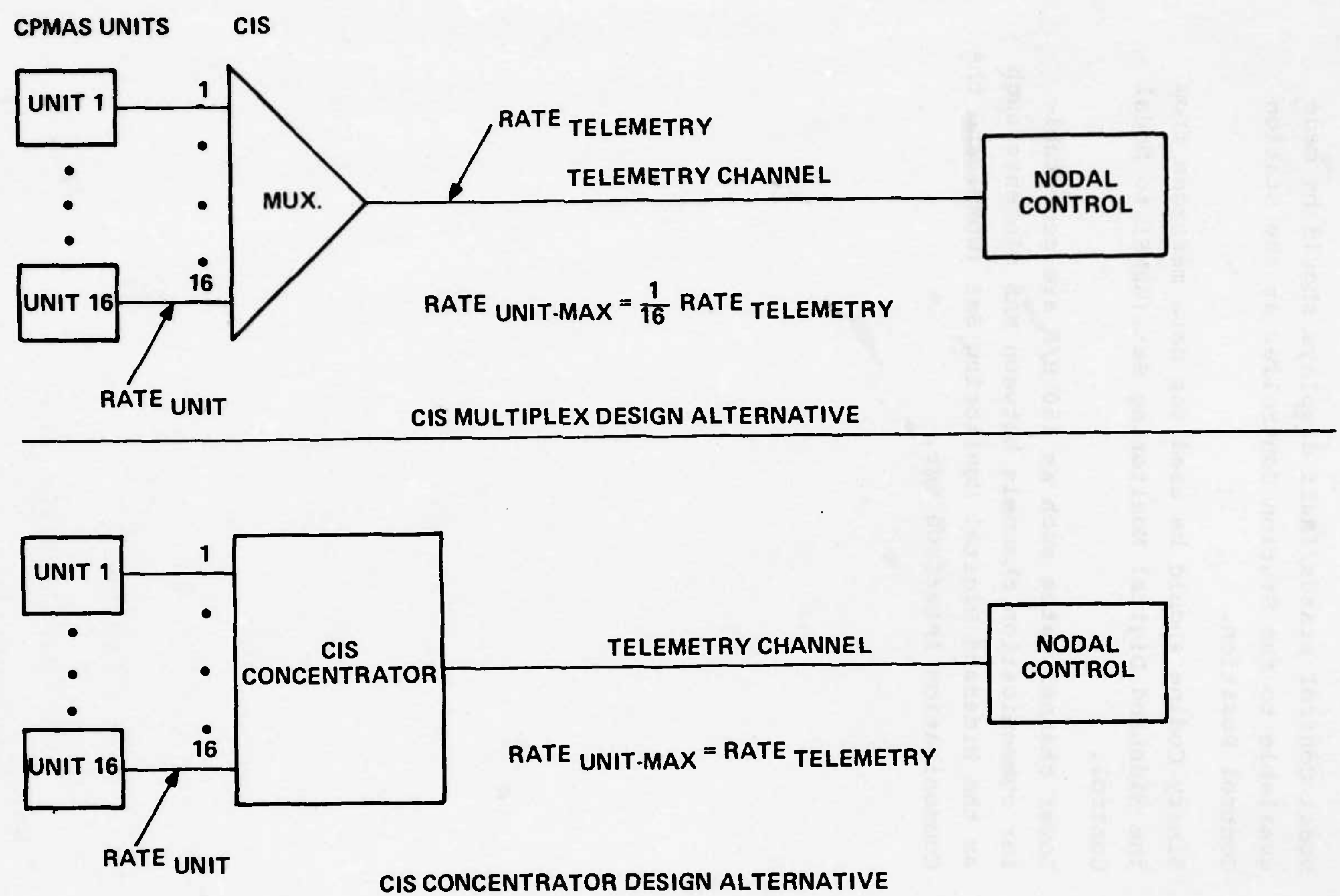


FIGURE 5-56. COMMUNICATIONS INTERFACE SET DESIGN ALTERNATIVES

4. Nodal Control status/fault displays should be made available to the Station Controller at the Station Control Position.

5. Binary Coding should be used for data messages from the Wideband Digital Monitoring Set (WDMS) to Nodal Control.

6. Lower channel rates such as 150 B/S are acceptable for communication channels between MAS elements such as the Wideband Digital Monitoring Set (WDMS) and the Communication Interface Set.

References for Section 5

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[6] L. Jankauskas, "Adaptive Estimation of Discrete Nonlinear Channels for Performance Assessment", IEEE Canadian Conference on Communications and Power, October, 1976.

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SECTION 6

TECHNICAL CONTROL MAN-MACHINE INTERFACE

A major functional element of CPMAS is the Technical Control man-machine interface. The effectiveness of CPMAS depends heavily upon the ability of the technical controller to access and use CPMAS data. The nodal control position which is shown in the CPMAS system block diagram in Figure 6-1, interfaces directly with the nodal control processing system (CPMAS-NCS). CPMAS displays are provided at the nodal controllers' CRT/Keyboard unit and hard copy is provided by the page printer. CPMAS data from all stations within the nodal area (up to 16 stations per Baseline Requirements Document) is transmitted to the CPMAS-NCS processing system where fault detection/isolation and transmission network performance assessment is accomplished. The results of these CPMAS processes are displayed for the nodal controller so that he can exercise judgement and make task assignments to maintenance and station control personnel.

The Fault Display is the specific type of display analyzed and described in this section. The Fault Display hierarchy in Figure 6-2 shows the method by which the nodal controller is led to levels of display detail in an orderly and coherent fashion. The Fault Summary display, the highest display in the hierarchy, provides an overview of the nodal area fault status. All faults in the nodal area which have not been cleared by the nodal controller are displayed in the fault summary display. The second level of the display hierarchy, the fault detail display, provides fault data for a specific fault listed in the fault detail display. The third and lowest level of the hierarchy provides alarm and status data for specific elements listed in the Fault-Detail display. The third level display provides status for a specific equipment, transmission path, trunk or circuit and is selected by a control entry on the Fault Detail display.

Each of the fault displays will be described in conjunction with the Digital Transmission System model. Faults identified on the model network will be displayed in the fault display examples.

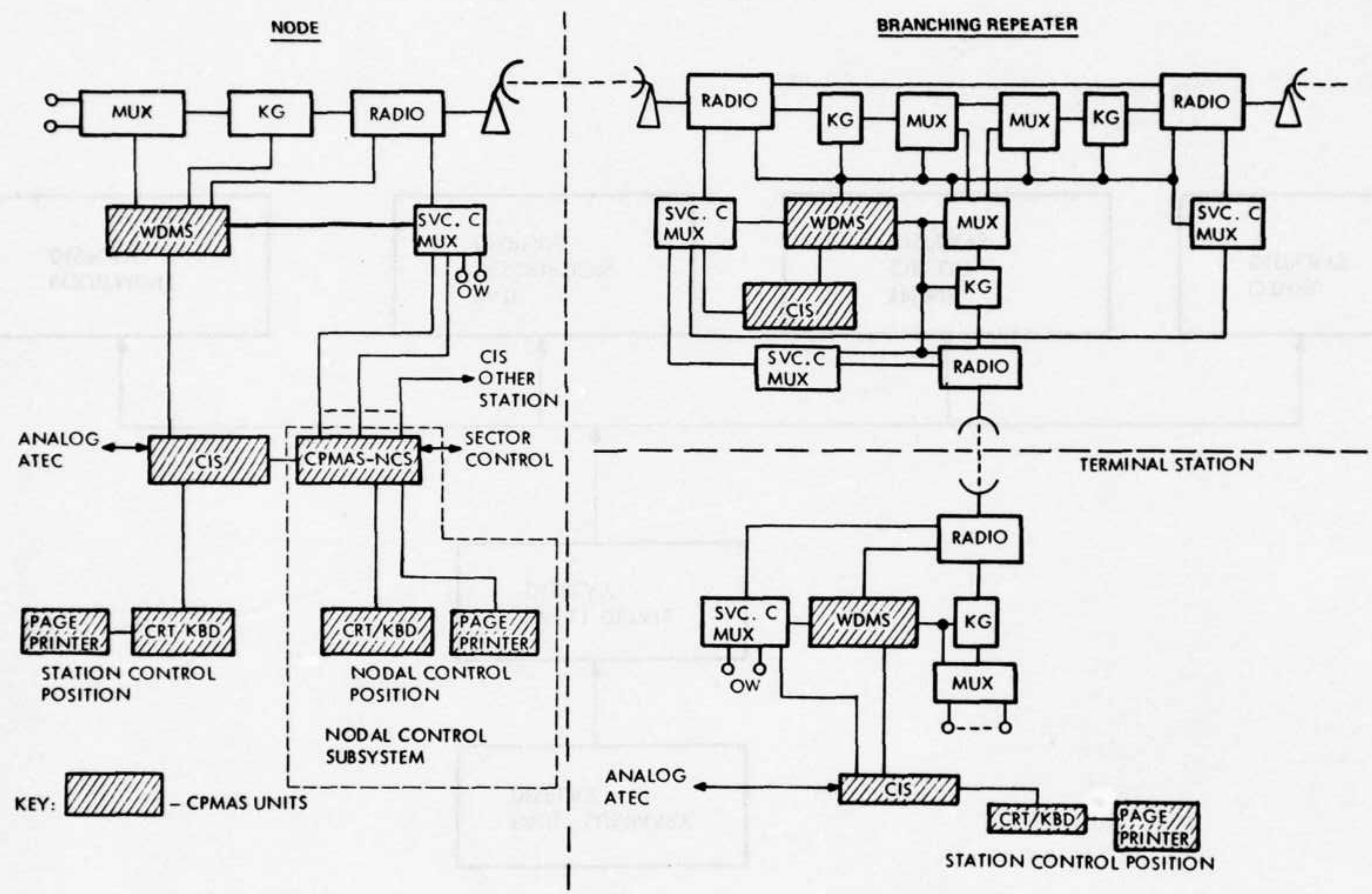


FIGURE 6-1. CPMAS SYSTEM BLOCK DIAGRAM

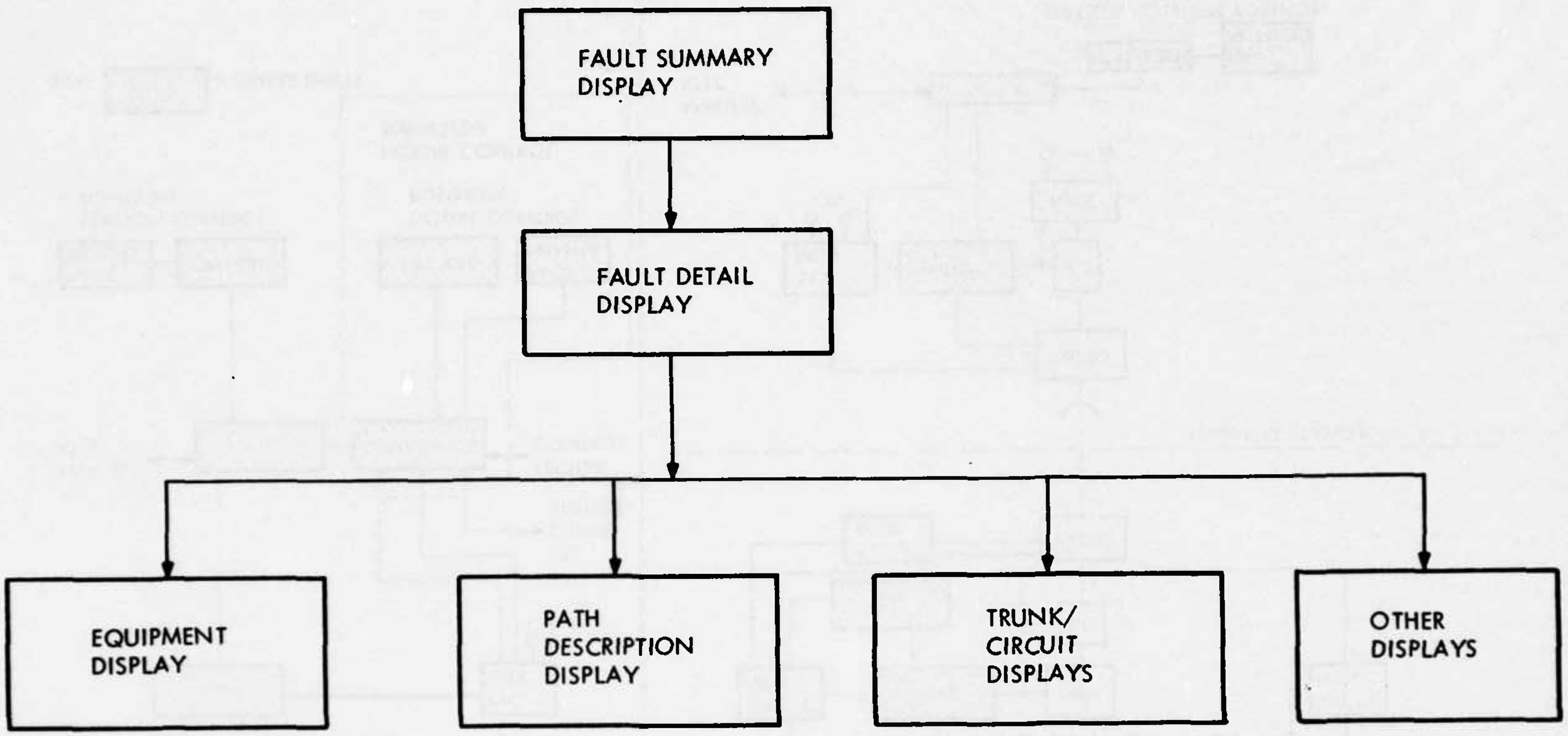


FIGURE 6-2. FAULT DISPLAY HIERARCHY

The fault display descriptions assume the following:

1. Individual group terminals of Second Level Multiplexers are alarmed.
2. Individual digital channel terminals of First Level Multiplexers are alarmed.
3. Analog ATEC reports analog channel alarms to the Nodal Control Processing System.

6.1 Fault Summary Display

The Fault Summary Display provides the overview of the nodal area fault status. All faults in the nodal area, not cleared by the nodal controller, appear on this display. An example of a Fault Summary Display shown in Figure 6-3 is used to describe the contents of the summary display. The first three lines of the display are reserved to alert the nodal controller to messages, faults not yet acknowledged and real time clock data. In line 1 of the display in Figure 6-3, two faults, specifically a channel fault and a link fault, are awaiting an acknowledgement. Line 1, the right hand side of the display, contains the date time group. Just below it in line 2 is real time with Julian day units. Line 4 contains the designation of the display type which for this case is Fault Summary. In the body of the display two lines are assigned to each fault, one of the lines contains fault data, the other provides control entries which permit acknowledging the fault, requesting a detail display for the fault, assigning the fault to a Station and clearing the fault. Space is also available in the second line for note entries by the nodal controller. A control is exercised by placing an X within the parentheses to the left of the control designation. In the case of assigning a fault to a station the station designator is entered within the parentheses. When the number of faults exceeds the display capacity of the CRT screen, scrolling or paging can be used to display the additional fault entries.

Line 6 provides the labels for the data column entries for fault data lines, lines 8, 11, 14, 17, and 20. Column 1 of a data line designates the severity of the fault. The severity of a fault is measured by the communication capacity affected and is thus designated by the capacity designation, e.g., Link (LK), Supergroup (SG, etc. The highest severity, Link (LK) is placed

```
                                   COLUMN NUMBER
LINE     :000000000111111111122222222223333333333444444444455555555556666666666777777777778:
NUMBER   :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
---------
    1    FAULT-CH-RH/FAULT-LK-RH/                                              17/1034 FEB 77
    2                                                                                  48/1034
    3
    4     (1)  (2) (3)   (4)          (5)   FAULT   SUMMARY       (6)                (7)
    5
    6    -SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--            TIME
    7
    8       CH   1A   RH DUUC9ACB ABC M0298 01 01 01  1ST-MUX,CH01,RCV             048/1033
    9           ( )ACK ( )DET (   )ASND ( )CLR (
   10
   11    LK          A            GHI M0300           RADIO-A,RF,TX                048/1012
   12           ( )ACK ( )DET (   )ASND ( )CLR (
   13
   14         SC     R   DUUK3NBC ABC M0298 02 08 23 07 SUBMUX,SC07,RCV            048/0954
   15           (X)ACK ( )DET (ABC)ASND ( )CLR (
   16
   17       GP       R   35JXC1   FOR M0109 01 01     1ST-MUX,GP,TX                048/0930
   18           (X)ACK ( )DET (FOR)ASND ( )CLR (
   19
   20        CH     RH   DUUC5ABT JKL M0692 01 01 01  1ST-MUX,CH01,RCV             048/0825
   21           (X)ACK ( )DET (JKL)ASND ( )CLR (
   22
   23
   24
```

FIGURE 6-3. NODAL CONTROL FAULT SUMMARY DISPLAY 1

at the left most side of the severity column and succeeding lesser severities are placed at positions to right with the least severity, Subchannel (SC) positioned in the right most side of the column. The severity display position aids the nodal controller to rapidly assess the number of higher severity faults.

Column 2 of the data line designates the priority if the failed communications circuit or trunk is assigned one.

The priority of a communication unit affects the severity of a fault. In the example in line 8, the 1A priority increased the severity of the fault and moved the CH severity one space to the left compared with the normal Channel severity position shown for the fault in line 20.

Column 3 of the data line designates the color level of the fault, e.g., Red (R), Amber (A), etc. A red alarm is a loss of communications whereas an amber alarm indicates degraded performance or a failure in a redundant equipment.

Column 4 identifies the circuit or trunk designator when the fault affects either a single circuit or trunk group. Column 5 specifies the communication element, e.g., link, supergroup, etc., that has failed. In the example in line 8, the channel that has failed is channel 01, of group 01, of link M0298 at station ABC. This failed channel can be observed in the Digital Transmission System Model Section shown in Figure 6-4. A circled 1 shows the location of the failed channel.

On the digital Transmission Model (Figure 6-4) the circled numbers 2, 3, 4 and 5 indicate the location of the faults displayed in display lines 11, 14, 17 and 20 respectively.

Column 6 provides an unambiguous identification of the faulted terminal. In the fault in line 8, the receive side of channel 01 of the 1st level Mux ABC-M0298-01-01 has failed. In order to unambiguously specify the faulted side of a channel, the receive or transmit side must be associated with an exact point as is the above case channel 01 at the 1st level multiplexer. Table 6-1 provides a list of common, equipment terminal fault location designations, to be used for column 6. The 7th column specifies the time at which the failure

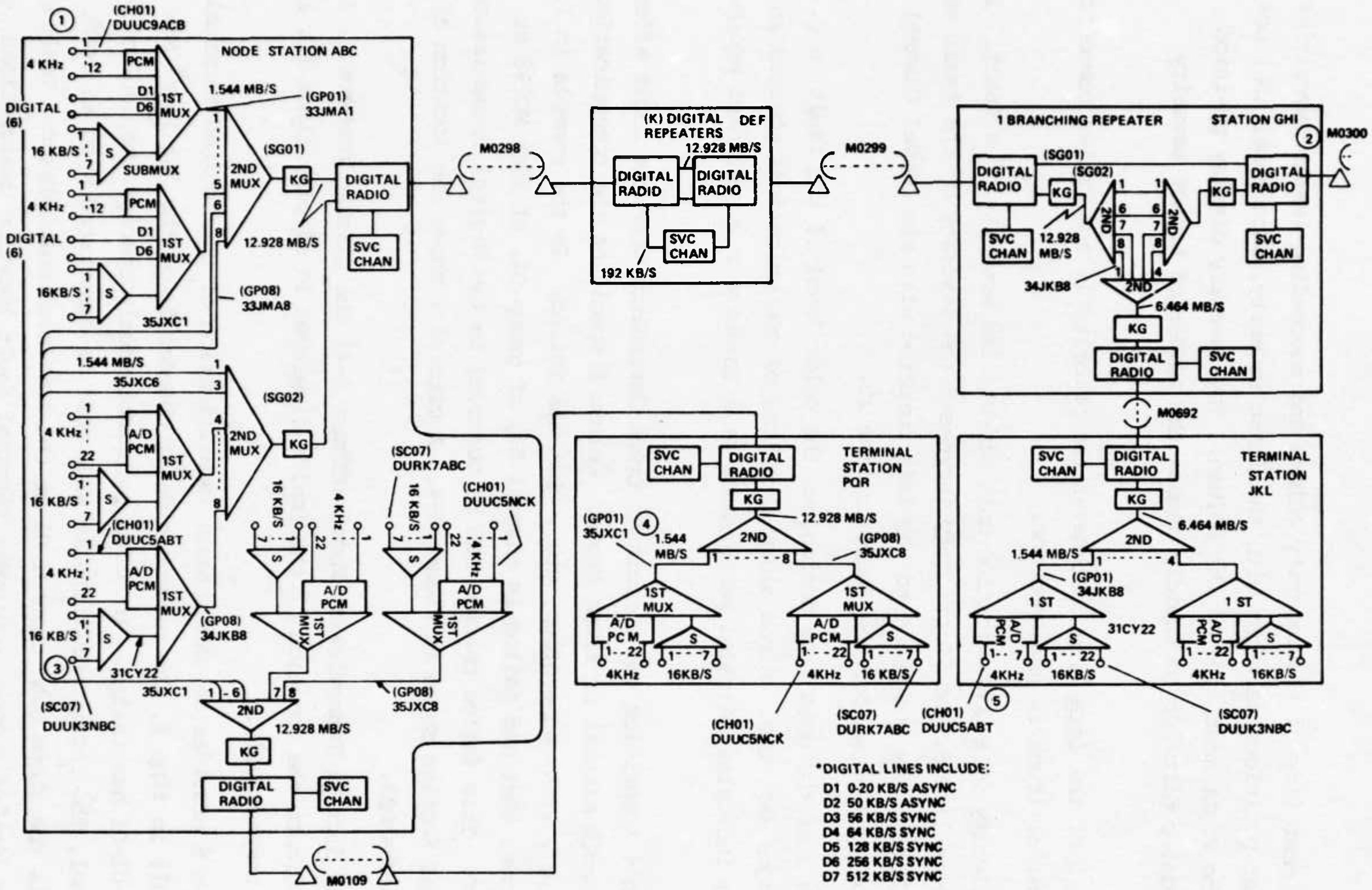


FIGURE 6-4. DIGITAL TRANSMISSION SYSTEM MODEL SECTION

TABLE 6-1

EQUIPMENT TERMINAL FAULT LOCATION DESIGNATIONS

1.	RADIO - A, RF, TX	23.	1ST - MUX, CHXX, TX
2.	RADIO - A, RF, RCV	24.	1ST - MUX, CHXX, RCV
3.	RADIO - A, BB, TX	25.	SUBMUX, CH, TX
4.	RADIO - A, BB, RCV	26.	SUBMUX, CH, RCV
5.	RADIO - B, RF, TX	27.	SUBMUX, SCXX, TX
6.	RADIO - B, RF, RCV	28.	SUBMUX, SCXX, RCV
7.	RADIO - B, BB, TX	29.	MODEM, MOD, TX
8.	RADIO - B, BB, RCV	30.	MODEM, MOD, RCV
9.	KG, CT, TX	31.	MODEM, BB, TX
10.	KG, CT, RCV	32.	MODEM, BB, RCV
11.	KG, PT, TX	33.	DAU, BB, TX
12.	KG, PT, RCV	34.	DAU, BB, RCV
13.	2ND - MUX - A, SG, TX	35.	DAU, MOD, TX
14.	2ND - MUX - A, SG, RCV	36.	DAU, MOD, RCV
15.	2ND - MUX - A, GPXX, TX	37.	RADIO - A, RF, TX
16.	2ND - MUX - A, GPXX, RCV	38.	RADIO - A, RF, RCV
17.	2ND - MUX - B, SG, TX	39.	RADIO - A, MOD, TX
18.	2ND - MUX - B, SG, RCV	40.	RADIO - A, MOD, RCV
19.	2ND - MUX - B, GPXX, TX	41.	RADIO - B, RF, TX
20.	2ND - MUX - B, GPXX, RCV	42.	RADIO - B, RF, RCV
21.	1ST - MUX, GP, TX	43.	RADIO - B, MOD, TX
22.	1ST - MUX, GP, RCV	44.	RADIO - B, MOD, RCV

was detected in Julian time. In the example in line 8, the time of failure is the 48th day at 1033 hours.

6.2 Nodal Control Displays - Fault Example 1

The simple fault assumed for the first fault example is shown in the Digital Transmission System Model Section in Figure 6-5. The fault causes the loss of transmission from the Group 8 terminal of second-level multiplexer PQR-M0109-01. Alarms resulting from the fault appear at the equipments indicated by circled alarms. The path of the group affected by the fault is shown by the dashed line from the 1st level mux PQR-M0109-01-08 to the 1st level Mux ABC-M0109-01-08.

The fault indicated above is displayed on line 8 of the Fault Summary Display shown in Figure 6-6. The severity is group; color is Red, Trunk 35JXC8 is affected; Group failed is PQR-M0109-01-08. The location of the fault is the transmit side of the 2nd level multiplexer A(PQR-M0109-01)'s Group 8 terminal. The time of the fault is 48th day 1034 hours.

This example is used to introduce the second display type which is also a member of the second level in the display hierarchy, the Fault Detail Display. By placing an X within the parentheses associated with Detail (DET) in line 9 of the Fault Summary Display (Figure 6-6), the Nodal Controller calls up the Fault Detail Display shown in Figure 6-7.

The Fault Detail Display provides more detailed information concerning the fault. The first three lines are reserved for messages to the Controller and are not used for the detail displays. The title of the display, Fault Detail is displayed on line 4. The next lines of all detail displays repeat the fault data line for the selected fault and column labels from the Fault Summary Display.

In the lines below all alarm indications associated with the fault are listed with the equipment and equipment type. A control entry is associated with each fault to provide for calling up a third level detail display; i.e., Fault Detail-Equipment Display which will be described later in Fault Example2.

From the detail display the fault is located at the transmit side of group 8 of the on-line 2nd level multiplexer Unit A. Sympathetic alarms,

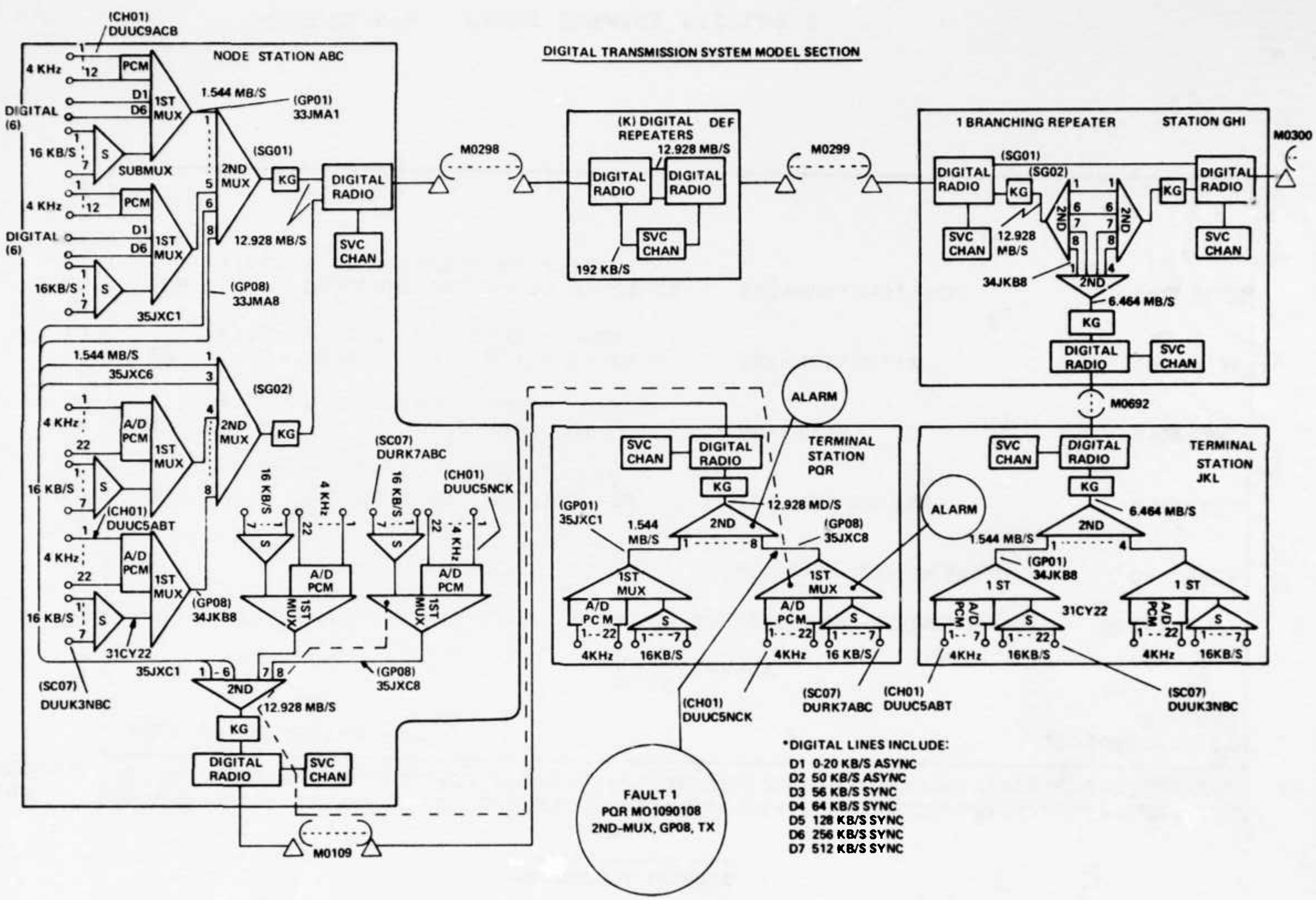


FIGURE 6-5. FAULT EXAMPLE 1

CHARACTER NUMBER

```
LINE    :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
--------+--------------------------------------------------------------------------------+
   1    :FAULT-GP-R/FAULT-GP-R/                                          17/1040 FEB 77
   2    :                                                                       48/1040
   3    :
   4    :                                 FAULT  SUMMARY
   5    :
   6    :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--        TIME
   7    :
   8    :  GP       R  35JXC8   PQR M0109 01 08       2ND-MUX-A,GP08-TX          048/1034
   9    :       ( )ACK ( )DET (    )ASND ( )CLR (
  10    :
  11    :  GP       R  34JKB8   ABC M0298 02 08       1ST-MUX,GP,TX              048/1013
  12    :       ( )ACK ( )DET (    )ASND ( )CLR (
  13    :
  14    : SG        R           ABC M0298 01          KG,CT,TX                   048/0645
  15    :       (X)ACK ( )DET (ABC)ASND ( )CLR (
  16    :
  17    :  GP       R  35JXC1   PQR M0109 01 01       1ST-MUX,GP,TX              048/0930
  18    :       (X)ACK ( )DET (PQR)ASND ( )CLR (
  19    :
  20    :   CH      R  DUUC5ABT JKL M0692 01 01 01    1ST-MUX,CH01,RCV           048/0825
  21    :       (X)ACK ( )DET (JKL)ASND ( )CLR (
  22    :
  23    :
  24    :
        +--------------------------------------------------------------------------------+
```

FIGURE 6-6. FAULT SUMMARY DISPLAY 2

CHARACTER NUMBER

```
LINE   :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
-------+--------------------------------------------------------------------------------+
     1 :FAULT-GP-R/FAULT-GP-R/                                            17/1040 FEB 77:
     2 :                                                                         48/1040:
     3 :                                                                                :
     4 :                                  FAULT  DETAIL                                 :
     5 :                                                                                :
     6 :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--       TIME     :
     7 :                                                                                :
     8 :  GP      R  35JXC8   PQR M0109 01 08       2ND-MUX,GP08-TX             048/1034:
     9 :                                                                                :
    10 :           EQUIPMENT              EQUIP.TYPE    ALARM     STATUS  CONTROL       :
    11 :2ND-MUX PQR M0109 01                 TD1193    GP08-TX      ALM    ( )DET       :
    12 :1ST-MUX PQR M0109 01 08              TD1192    GP-RCV       ALM    ( )DET       :
    13 :1ST-MUX PQR M0109 01 08              TD1192    FRAME LOSS   ALM    ( )DET       :
    14 :                                                                                :
    15 :  PATH                                                                          :
    16 :     PQR-M0109-ABC                                                              :
    17 :                                                                                :
    18 :  TRUNKS AFFECTED                                                               :
    19 :     35JXC8                                                                     :
    20 :                                                                                :
    21 :  CIRCUITS AFFECTED                                                             :
    22 :     DUUC5NCK  DURK7ABC                                                         :
    23 :                                                                                :
    24 :                                                                                :
       +--------------------------------------------------------------------------------+
```

FIGURE 6-7. FAULT DETAIL DISPLAY 1

Group Receive, and Frame Loss are indicated at the 1st level multiplexer. The 2nd level multiplexer's redundant Unit B, as indicated in the display, has a power supply failure. If it were not for this failure Unit B would have automatically been switched on-line, the 1st level sympathetic alarms would not have occurred and the alarm would have been classed an Amber alarm. The Fault Detail Display provides a summary path description using only station and link designators and also identifies trunks or circuits affected by the fault.

6.3 Nodal Control Displays - Fault Example 2

A more complex fault is assumed for the second fault example. The second fault is shown in the Digital Transmission System Model Section in Figure 6-8. The fault causes the loss of transmission from the Group terminal of the 1st Level Multiplexer ABC-M0298-02-08. The path of the group affected by the alarm is shown by the dashed line from the 1st level multiplexer ABC-M0298-02-08 to the 1st Level Multiplexer JKL-M0692-01-01. Alarms resulting from the fault appear at equipments indicated by circled A's.

The second fault example is displayed on line 11 of the Fault Summary Display in Figure 6-6. The Fault Detail Display for the second fault example which is shown in Figure 6-9 lists all of the terminal alarms associated with the fault and provides the capability to select 3rd level detail displays for equipments, path, circuits and trunks affected. An X entered within the parentheses in Line 10 would obtain the Fault Detail Equipment display shown in Figure 6-10. The Fault Detail Equipment Display repeats the Fault Summary data line and provides all status available for the selected equipment which in this case is 1st Level Multiplexer ABC-M0298-02-08. This 1st Level Multiplexer is the failed multiplexer. Group transmit and BITE alarms and a Frame Error Rate of 10^{-9} are indicated in the detail display.

A Fault Detail-Equipment display for the 2nd Level Mux ABC-M0298-02 is given in Figure 6-11. This display shows the sympathetic alarms, Sigma Group A Receive Alarm and a Group 2-A Receive Alarm. It also indicates that the multiplexer is a TD1193 and that the "A" Multiplexer is on-line.

The nodal Controller can return to the Fault Detail Display to request other third level detail displays; for example, path description, trunk or

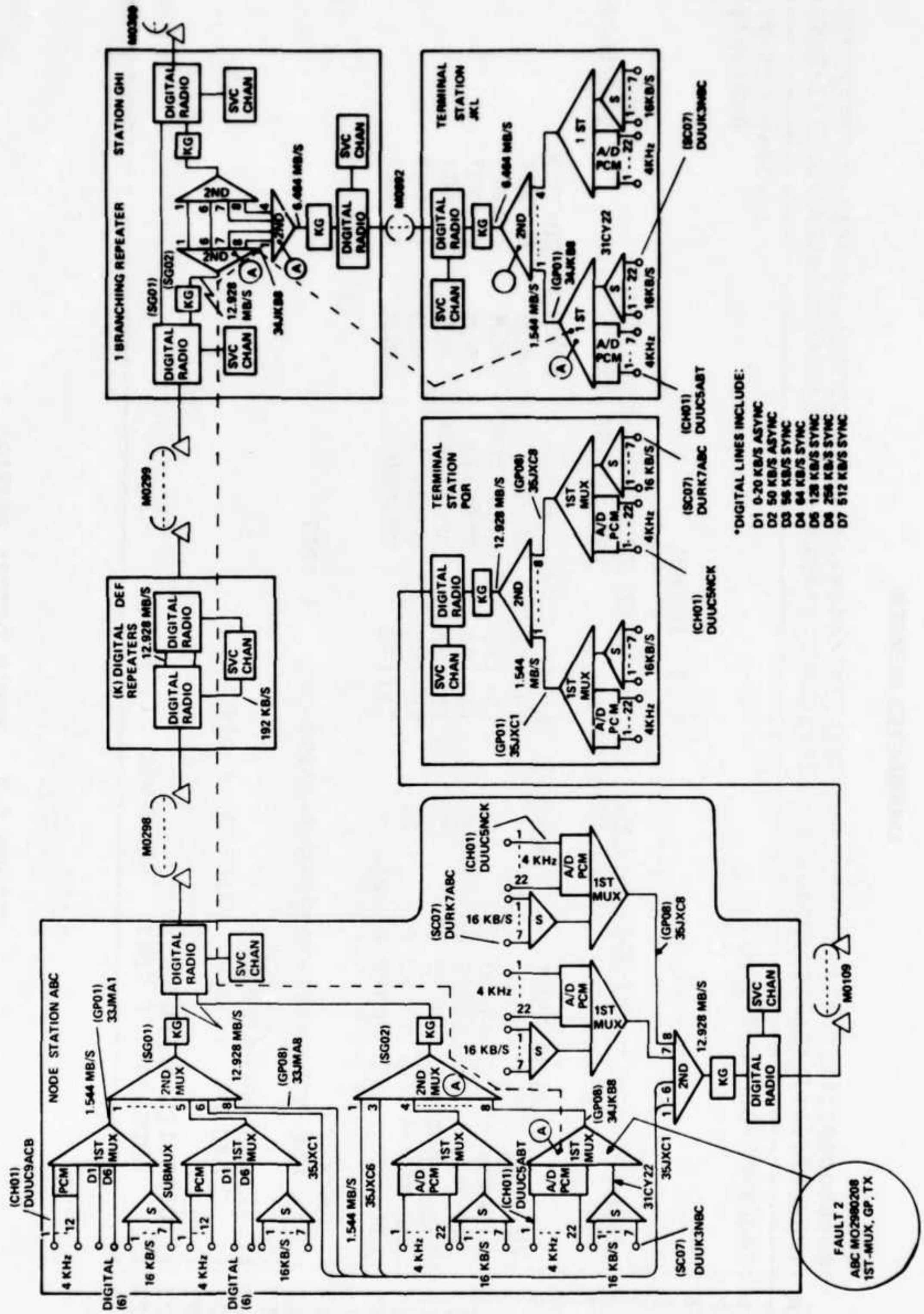


FIGURE 6-8. FAULT EXAMPLE 2

```
                                 CHARACTER NUMBER
LINE    :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
--------+--------------------------------------------------------------------------------+
     1  :FAULT-GP-R/FAULT-GP-R/                                            17/1040 FEB 77:
     2  :                                                                        048/1040:
     3  :                                                                                :
     4  :                                FAULT  DETAIL                                   :
     5  :                                                                                :
     6  :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--          TIME  :
     7  :  GP      R  34JKB8   ABC M0298 02 08        1ST-MUX,GP,TX                048/1040:
     8  :                                                                                :
     9  :            EQUIPMENT         ON-LINE  EQUIP.TYPE    ALARM     STATUS  CONTROL    :
    10  :1ST-MUX    ABC M0298 02 08             TD1192      GP,TX       ALM    ( )DET     :
    11  :2ND-MUX-A  ABC M0298 02          ON    TD1193      GP08,RCV    ALM    ( )DET     :
    12  :2ND-MUX-A  GHI M0299 02          ON    TD1193      GP08,TX     ALM    ( )DET     :
    13  :2ND-MUX-A  GHI M0692 01          ON    TD1193      GP01,RCV    ALM    ( )DET     :
    14  :2ND-MUX-A  JKL M0692 01          ON    TD1193      GP01,TX     ALM    ( )DET     :
    15  :1ST-MUX    JKL M0692 01 01             TD1192      GP,RCV      ALM    ( )DET     :
    16  :                                                                                :
    17  :  PATH                                                                          :
    18  :     ABC-M0298-DEF-M0299-GHI-M0692-JKL    ( )DET                                :
    19  :                                                                                :
    20  :  TRUNKS AFFECTED                                                               :
    21  :     34JKB8  ( )DET   31CY22  ( )DET                                            :
    22  :                                                                                :
    23  :  CIRCUITS AFFECTED                                                             :
    24  :     DUUC5ART  ( )DET   DUUK3NBC  ( )DET                                        :
        +--------------------------------------------------------------------------------+
```

FIGURE 6-9. FAULT DETAIL DISPLAY 2

CHARACTER NUMBER

```
LINE    :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
--------------------------------------------------------------------------------------------
   1    FAULT-GP-R/FAULT-GP-R/                                            17/1040 FEB 77
   2                                                                            048/1040
   3
   4                                FAULT  DETAIL-EQUIPMENT
   5
   6    -SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--          TIME
   7      GP      R  34JKB8   ABC M0298 02 08       1ST-MUX,GP,TX               048/1013
   8
   9                             EQUIPMENT  STATUS
  10
  11    1ST-MUX ABC M0298 02 08        TD1192
  12
  13      MEASUREMENT      STATUS
  14    PWR SUP              OK
  15    FRAME LOSS           OK
  16    GROUP TX            ALM
  17    GROUP RCV            OK
  18    BITE                ALM
  19    CARRIER GROUP        OK
  20    FER                  09
  21
  22
  23
  24
```

FIGURE 6-10. FAULT DETAIL-EQUIPMENT DISPLAY 1

CHARACTER NUMBER

```
LINE     :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER   :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
---------+--------------------------------------------------------------------------------+
       1 :FAULT-GP-R/FAULT-GP-R/                                          17/1040 FEB 77:
       2 :                                                                      048/1040:
       3 :                                                                              :
       4 :                                FAULT  DETAIL-EQUIPMENT                       :
       5 :                                                                              :
       6 :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--        TIME   :
       7 :  GP      R  34JKB8   ABC M0298 02 08        1ST-MUX,GP,TX            048/1013:
       8 :                                                                              :
       9 :                             EQUIPMENT  STATUS                                :
      10 :                                                                              :
      11 :2ND-MUX ABC M0298 02          TD1193           ON-LINE A                      :
      12 :                                                                              :
      13 :  MEASUREMENT     STATUS          MEASUREMENT     STATUS                       :
      14 :BITE A             OK            SG-A,TX          OK                          :
      15 :BITE B             OK            SG-B,TX          OK                          :
      16 :PWR SUP-A          OK            FRAME LOSS-A     OK                          :
      17 :PWR SUP-B          OK            FRAME LOSS-B     OK                          :
      18 :SIGMA GP-A,RCV     ALM                                                        :
      19 :GP02,RCV           ALM                                                        :
      20 :SIGMA GP-B,RCV     OK                                                         :
      21 :SIGMA GP-A,TX      OK                                                         :
      22 :SIGMA GP-B,TX      OK                                                         :
      23 :SG-A,RCV           OK                                                         :
      24 :SG-B,RCV           OK                                                         :
         +--------------------------------------------------------------------------------+
```

FIGURE 6-11. FAULT DETAIL-EQUIPMENT DISPLAY 2

CHARACTER NUMBER

```
LINE    :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
--------+--------------------------------------------------------------------------------+
     1  :FAULT-GP-R/FAULT-GP-R/                                          17/1040 FEB 77:
     2  :                                                                      048/1040:
     3  :                                                                              :
     4  :                               PATH  DESCRIPTION                              :
     5  :                                                                              :
     6  :-SEV--PR COL CKT/TRNK STA LINK  SG GP CH SC EQUIPMENT-LOCATION--          TIME :
     7  :  GP      R  34JKBS   ABC M0298 02 08       1ST-MUX,GP,TX             048/1040:
     8  :      EQUIPMENT                EQUIPMENT TYPE           TERMINAL ALARM         :
     9  :1ST-MUX    ABC M0298 02 08     TD1192                   GP,TX                 :
    10  :2ND-MUX-A  ABC M0298 02        TD1193                   GP02,RCV              :
    11  :KG         ABC M0298 02        KG81                                           :
    12  :RADIO-A    ABC M0298           AN/FRC-( )                                     :
    13  :RADIO-A    DEF M0298           AN/FRC-( )                                     :
    14  :RADIO-A    DEF M0299           AN/FRC-( )                                     :
    15  :RADIO-A    GHI M0299           AN/FRC-( )                                     :
    16  :KG         GHI M0299 02        KG81                                           :
    17  :2ND-MUX-A  GHI M0299 02        TD1193                   GP08,TX               :
    18  :2ND-MUX-A  GHI M0692 01        TD1193                   GP01,RCV              :
    19  :KG         GHI M0692 01        KG81                                           :
    20  :RADIO-A    GHI M0692           AN/FRC-( )                                     :
    21  :RADIO-A    JKL M0692           AN/FRC-( )                                     :
    22  :KG         JKL M0692 01        KG81                                           :
    23  :2ND-MUX-A  JKL M0692 01        TD1193                   GP01,TX               :
    24  :1ST-MUX    JKL M0692 01 01     TD1192                   GP,RCV                :
        +--------------------------------------------------------------------------------+
```

FIGURE 6-12. DETAIL PATH DESCRIPTION DISPLAY

circuit displays. A Path Description Display request is executed by placing an X within the parentheses on line 18 of the Fault Detail Display in Figure 6-9. The Detail Path Description Display is shown in Figure 6-12. As in all other displays the first three lines are reserved for alerting the controller to unacknowledged faults and/or messages for the controller. The path description display lists each equipment in the fault path, its equipment type and any terminal alarm at the equipment. The fault data from the original summary fault display is repeated on line 7 of the Path Description.

SECTION 7

DESCRIPTION OF RECOMMENDED CPMAS APPROACH

The wideband digital CPMAS requirements as described in Section 4, and the recommended approaches to performance assessment, trend analysis and fault detection/isolation for the presently envisioned DCS digital transmission system as developed in Section 5 of this report, have been consolidated to create a wideband CPMAS digital design for the Sector, Nodal and Station levels of DCS SYSCON.

Section 7.1 presents a system description of CPMAS which includes the recommended allocation of the functional requirements developed in Section 4, an introduction to the CPMAS functional modules which result from the function allocation, and the interrelationships among these functional modules.

Section 7.2 provides descriptions of the functional modules introduced in Section 7.1.

Section 7.3 discusses hardware requirements which result from the realization of the CPMAS functional modules into individual CPMAS units, and presents hardware designs and recommendations for these units.

Section 7.4 presents software requirements alternatives and recommendations for CPMAS and the individual CPMAS units.

7.1 CPMAS System Description

The CPMAS system design is based upon CPMAS requirements described in Section 4, the DCS techniques and methods described in Section 5, and the functional ATEC system as described in the ATEC System Description and Base Line Requirements Document (BLRD). The CPMAS design is structured for the CPMAS hierarchy shown in Figure 7-1.

Transmission problems or faults which only affect equipment at a station are the responsibility of Station and Nodal Control. Transmission problems or faults which affect equipments or links within the nodal area are the responsibility of the Nodal Control. Problems and faults which affect a number of nodal areas within a sector are the responsibility of Nodal and Sector Control.

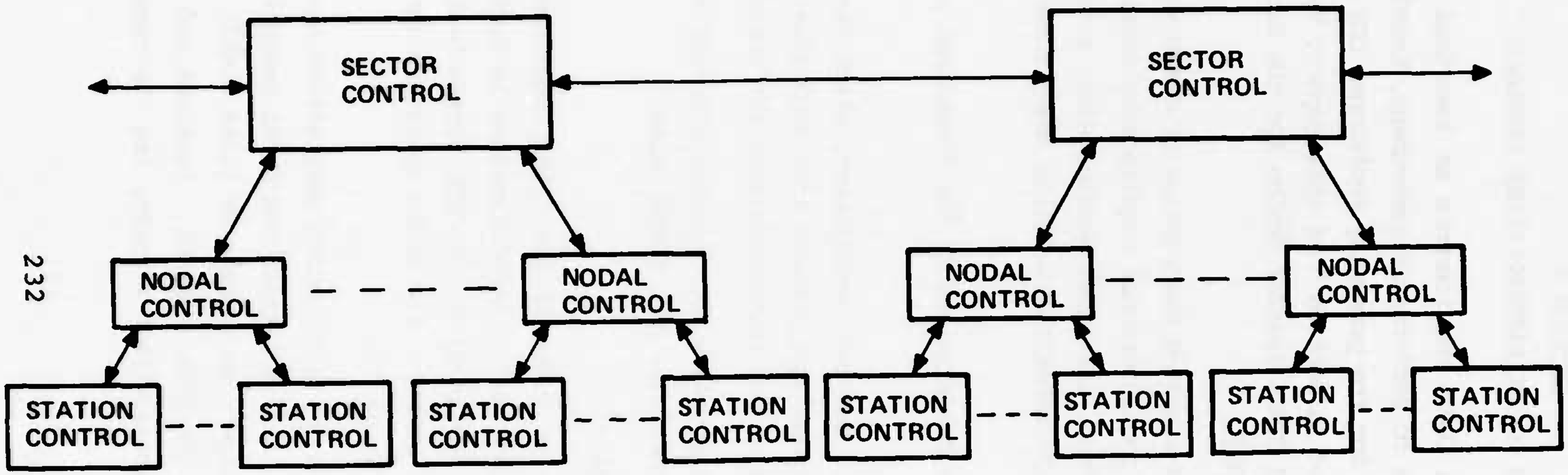


FIGURE 7-1. CPMAS HIERARCHY

The basic CPMAS functions occur at the Station and Nodal levels. Measurements are made at the station and transmitted directly to Nodal Control for Automated Processing. Sector Control receives processed CPMAS data reports, processed at Nodal Control, and perform functions similar to the Nodal Control functions for the higher levels of the SYSCON hierarchy. Inter-area faults are always reported to a higher level in the hierarchy until the failed resources are all members of the controller's area of responsibility. It is at this level of the hierarchy that corrective actions are determined.

Station CPMAS functions consist primarily of monitoring and assessing performance of digital transmission equipments at the station, and reporting the monitoring and performance assessment data by exception directly to Nodal Control. Nodal Control receives CPMAS data from all stations within its nodal area and performs status monitoring, performance assessment, fault detection/isolation, reporting and corrective action functions for them. Station control can obtain CPMAS data from other stations or communicate with other station controllers via Nodal Control. Station Control is capable of stand-along operation when Nodal Control is not connected or is inoperative. In this mode, performance monitor and assessment data is reported by exception to the station controller via the station control position. The station controller then manually performs fault isolation and takes or commands corrective actions for local station faults.

Four CPMAS units are used to service the first two levels of CPMAS hierarchy - Station and Nodal Control. The units are:

a. CPMAS-D which monitors and performs performance assessment of digital transmission equipment at a station;

b. CPMAS-NCS which performs nodal control processing and provides the Nodal Controller's man-machine interface for control of the nodal area of responsibility;

c. Communications Interface Set (CIS) which provides the communication interface among CPMAS units at a station, the Station Control Position and Nodal Control Subsystem; and,

d. Station Controller Position which provides the station man-machine interface.

Figure 7-2 shows the units applied to the nodal station, a branching repeater station and a terminal station of the model subnetwork. In the nodal station, the CPMAS-D unit monitors the multiplexer, KG and radio equipments and transfers the data on a report by exception basis, i.e., CPMAS data is transmitted to the Station Control Position and Nodal Control when a fault occurs or a measurement threshold is reached. Complete CPMAS data can also be requested from CPMAS-D by either Station or Nodal Control.

The CPMAS-NCS, which includes CPMAS Nodal Control Processing System and the Nodal Control Position, receives the requested status and performance assessment data from the CPMAS-D units of all stations within the nodal area, performs fault detection/isolation and performance assessment for the nodal area, displays status and alarms, provides reports to the responds to direction from Sector Control, provides CPMAS data transfer and message communications between station controls within the nodal area, maintains and displays restoral and alternate routing plans and system connectivity for the nodal area, maintains CPMAS parameter histories and data bases for the nodal area and transmits directed actions to station controllers.

The Communication Interface Set (CIS) provides a communication interface between the CPMAS-D unit(s) and Station Control Position at the station, and the Nodal Control Processing System. The CIS also provides the interface between the monitoring and performance assessment units (CPMAS-D) and the Station Control Position. The CIS performs message format, message protocol and error control functions. The CIS can communicate with nodal control via a local connection, wireline or telemetry channel in the digital transmission system.

The Station Control Position is equipped with a CRT/KBD unit to perform its display and control functions, and a page printer to provide hard copy record. The Station Control Position is primarily a man-machine interface which communicates with the other CPMAS units via the CIS.

The branching repeater station in Figure 7-2 applies the CPMAS-D and CIS units in the same manner as the nodal station, except that the CIS

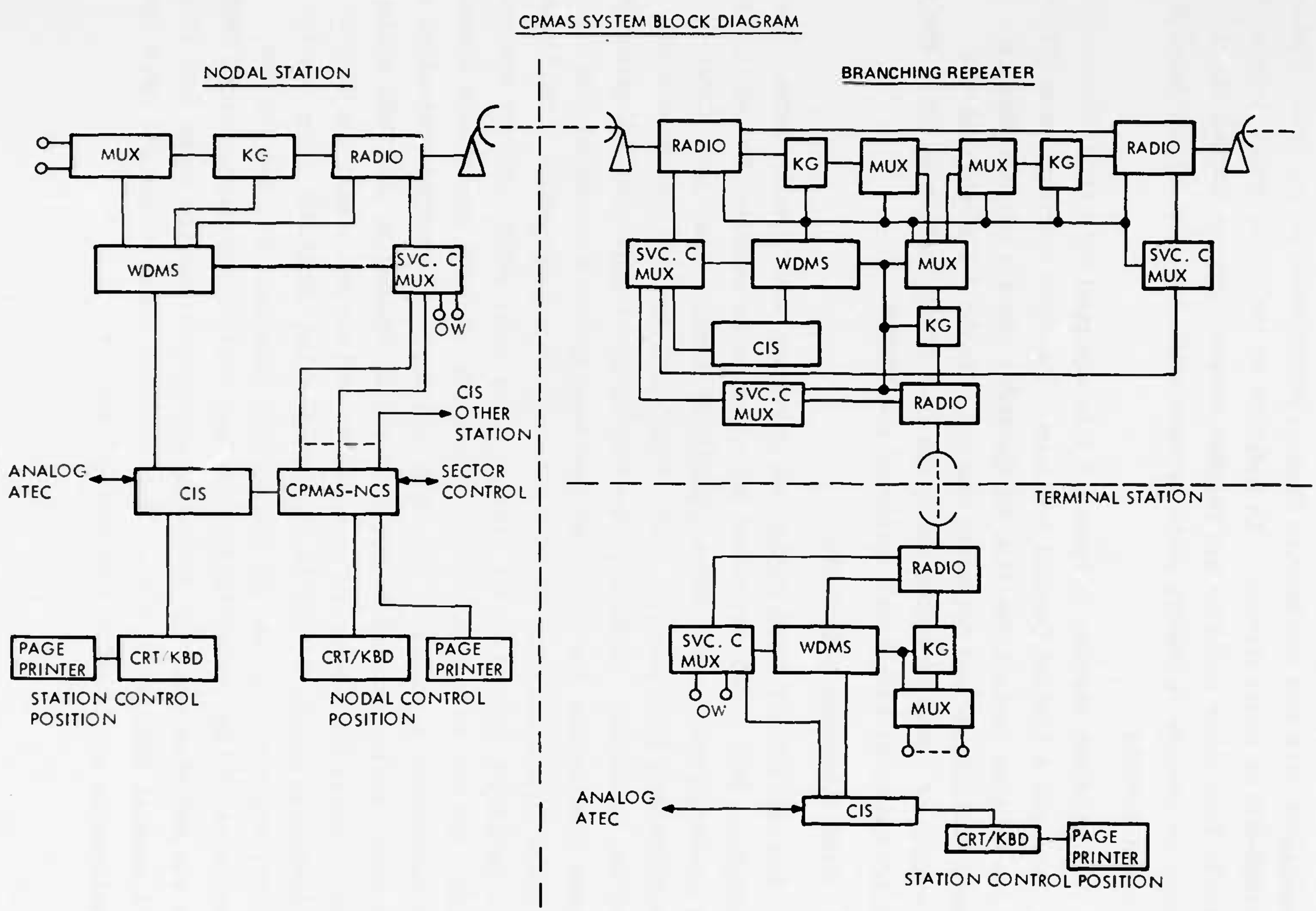


FIGURE 7-2. CPMAS SYSTEM BLOCK DIAGRAM

interface to Nodal Control is connected to a telemetry channel input of the Service Channel Multiplexer. The CPMAS data is transmitted via the radio transmission link and the Service Channel Multiplexer at the nodal station to CPMAS-NCS at Nodal Control. In addition to the local CPMAS, telemetry channels from other stations are patched between Service Channel Multiplexers to provide telemetry paths between other stations in the network and Nodal Control.

The terminal station in Figure 7-2 is equipped with the CPMAS-D and CIS units and a Station Control Position. The CIS interfaces with CPMAS-D and the Station Control Position to the Nodal Control via the Service Channel Multiplexer and Telemetry Channel. Table 7-1 summarizes the allocation of CPMAS functions among the four CPMAS functional units for the station and nodal hierarchal levels of DCS SYSCON.

7.2 CPMAS Subsystem Description

The preliminary CPMAS design was discussed functionally above. In that discussion, four CPMAS functional subsystems were proposed for monitoring and assessing the digital DCS transmission system. They are: CPMAS-D, Communications Interface Set (CIS), CPMAS-NCS, and the station control position functions. CPMAS-D is the Measurement Acquisition Subsystem (MAS) element responsible for the in-service measurement of wideband digital multiplex hierarchies and mission bit streams and equipments. The CPMAS-D MAS element is located at all digital radio (FKV, DRAMA, DAU/FM) equipped sites. The CIS is responsible for providing the data interchange between the measurement elements of the CPMAS system, the technical controller and the Nodal Control Subsystem (NCS). A CIS is located at all CPMAS equipped sites. The nodal processing required to monitor and assess the digital transmission equipment will be performed by the CPMAS-NCS. The Station Control Position provides the man-machine interface required for the station controller to communicate to, and receive information from, CPMAS-NCS and the MAS elements. The following paragraphs describe these four subsystems to a general functional level. More detailed descriptions and functional requirements are found in Sections 7.3 and 7.4.

TABLE 7-1. CPMAS UNIT FUNCTION ALLOCATIONS

	CPMAS UNITS FOR THE NODAL AND STATION HIERARCHAL LEVELS			
	CPMAS-D	CPMAS-NCS	CIS	STATION CONTROL POSITION
FUNCTIONS	. Station Digital Transmission equipment and facility monitoring and assessment . Station fault reporting . Station status reporting on request . Station control functions . Full duplex communications . Self test	. Nodal area status display . Restoral and alternate routing . DCS connectivity data base . Semi-automated report preparation . Fault isolation . Performance assessment . Parameter history . Event logging . Full duplex communications	. CPMAS-D/Nodal control comm. interface . CPMAS-D/Station controller position comm. interface . Nodal Control/ Station controller position comm. interface	. Keyboard input . Message/Report presentation . Full duplex communications . Visual display . Data and format storage . Hard copy capability . Funcional request capability

7.2.1 CPMAS-D

The CPMAS-D function provides the means to monitor and assess the performance of the digital multiplexer hierarchy, the encryption equipment, the digital radio subsystem (FKV, DRAMA, DAU/FM), the service channel equipment and the remote station facilities. CPMAS design calls for the monitoring of equipment BITE status alarms, the processing of radio/multiplexer frame error pulses, the processing of radio analog parameters, the employment of performance assessment techniques, the execution of control commands such as redundant equipment switchovers, and the execution of self test functions.

Figure 7-3 presents a functional block diagram of the CPMAS-D. CPMAS-D detects fault or out-of-tolerance conditions automaticlaly via the binary alarm, error pulse, analog parameter, performance assessment data acquisition modules, and the data acquisition control and computation module. These modules also acquire desired performance monitor and assessment data upon request. CPMAS-D control commands are carried out by the command recognition and command execution modules. The communications interface module provides the means to interface the CPMAS-D to the CPMAS function.

Based upon the recommendations of Section 5, the CPMAS-D monitors all digital transmission equipment and facility binary alarm/status points, error pulse points and analog parameter points. Performance assessment data acquisition, control, and computation consist of an adaptive digital radio channel estimation technique.

7.2.2 Communications Interface Set (CIS)

Data interchange between the detection and measurement elements of the CPMAS system, the technical controller and the Nodal Control Subsystem will be centralized at a station. This function is accomplished by the Communications Interface Set (CIS). Figure 7-4 presents a functional description of the CIS. The CIS also provides the means for inter-station communications (via the NCS). Additionally, the CIS provides Automatic Repeat Request (ARQ) messages, forwards measurement acquisition messages and transmits data/parameters.

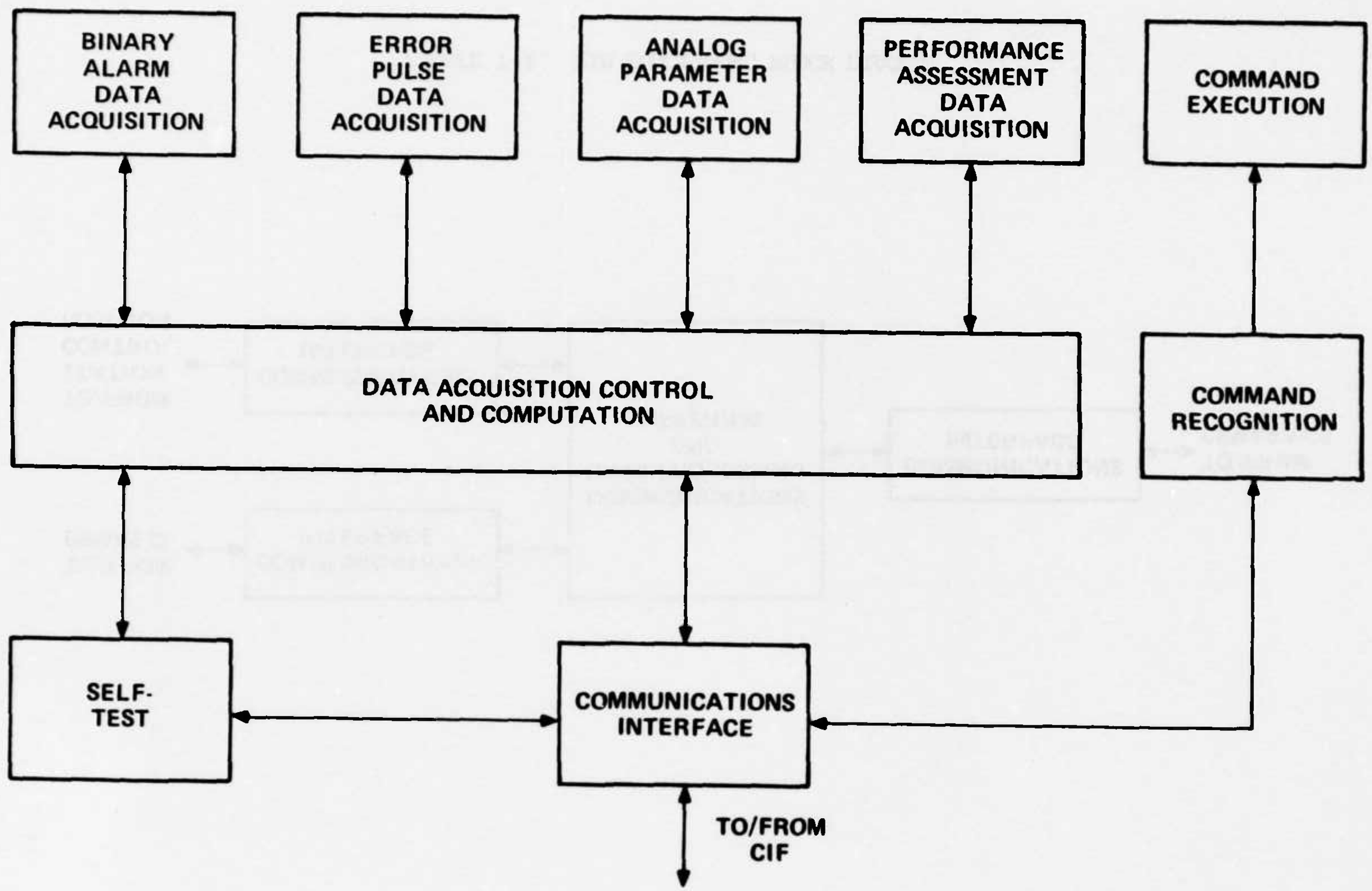


FIGURE 7-3. CPMAS-D FUNCTIONAL BLOCK DIAGRAM

FIGURE 7-4. CIS FUNCTIONAL BLOCK DIAGRAM

Associated with these functions will be the necessary protocol, source/destination recognition and command recognitions.

7.2.3 CPMAS-NCS

The Nodal Control Subsystem (NCS) satisfies the nodal control requirements. These requirements are broadly defined as: nodal status display, restoral/alternate routing, DCS connectivity, report preparation, fault detection/isolation, performance assessment, parameter history and event logging.

Figure 7-5 shows the functions that must be performed by the NCS as well as the functions necessary for the NCS to interact with the Nodal control position, station control position and the MAS elements.

CPMAS-NCS will perform the nodal processing necessary to monitor and assess the digital transmission system. In particular, CPMAS-NCS will perform the NCS functions associated with the digital transmission equipment. CPMAS-NCS, therefore, will not be responsible for the DCS connectivity, restoral/alternate routing and report preparation.

7.2.4 Station Control Position Function

The Station Control Position function provides the station controller with a man-machine control and communication interface with the CPMAS-D function at his station, the CPMAS-NCS and nodal controller, and other station controllers via the CPMAS-NCS. The communications path for the terminal function is provided through the Communication Interface Set (CIS). The Station Control Position functional block diagram is shown in Figure 7-6.

7.3 CPMAS Hardware Description

This section presents the hardware design requirements and the design approaches chosen for the four functional subsystems introduced in Section 7.1 and described in Section 7.2 of this report.

7.3.1 CPMAS Hardware Description

The basic hardware requirements for the CPMAS equipments evolve from the structure of the DCS digital transmission system and the hierarchal nature of DCS SYSCON. Both station and nodal level hardware must be adapatable both to many different configurations of digital transmission equipment and to many

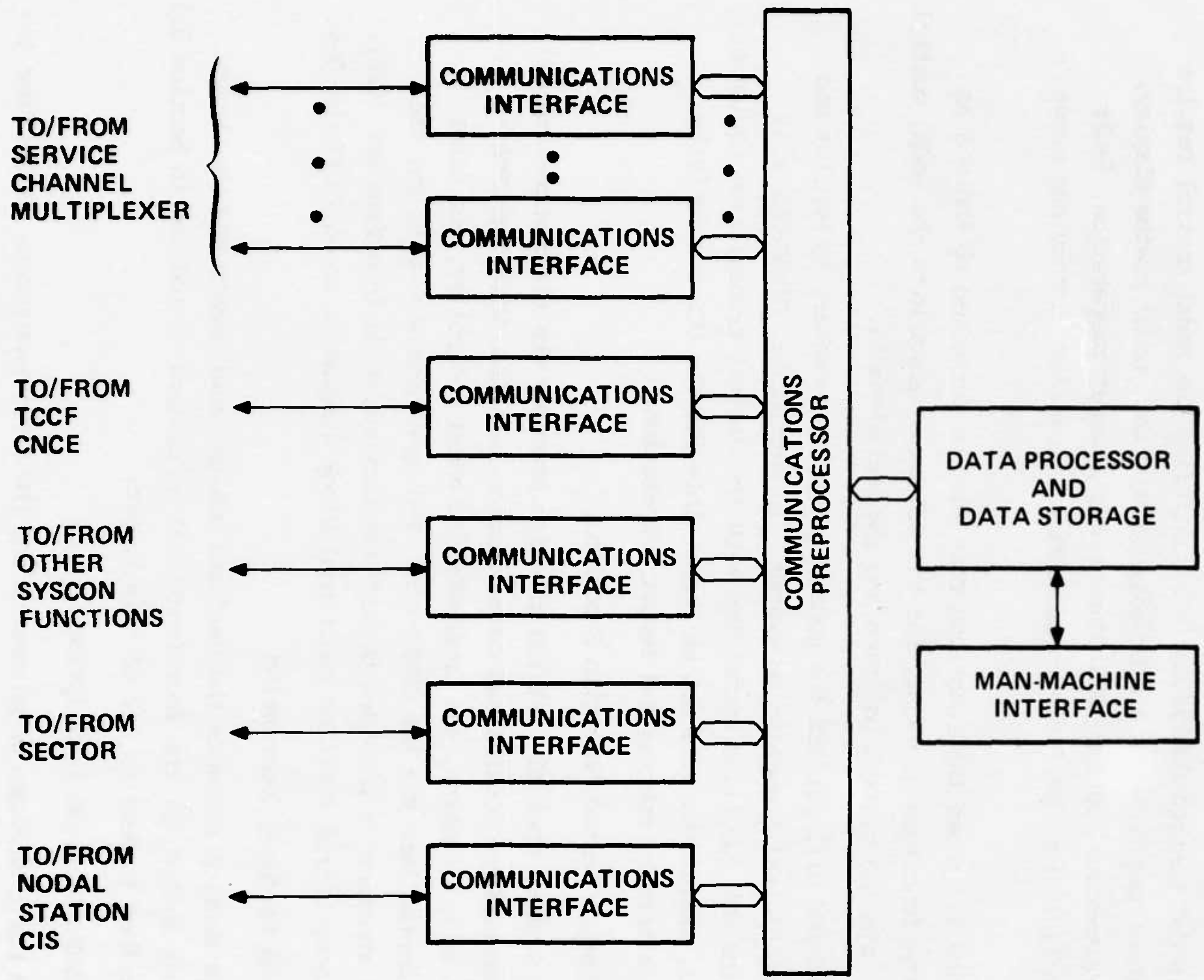


FIGURE 7-5. CPMAS-NCS FUNCTIONAL BLOCK DIAGRAM

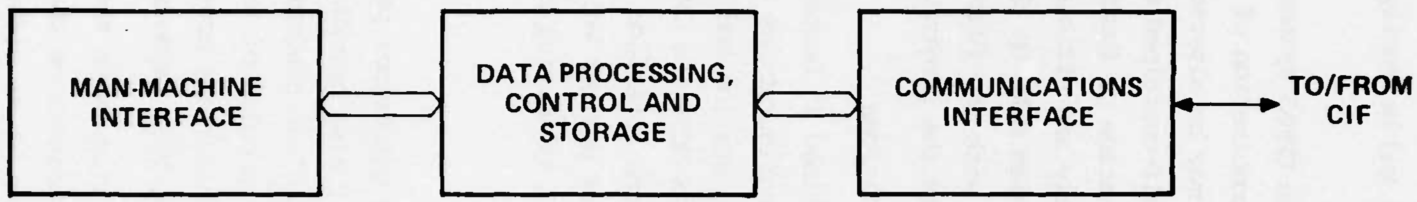


FIGURE 7-6. STATION CONTROL POSITION FUNCTIONAL BLOCK DIAGRAM

changes in these configurations over the life of the CPMAS equipment. Thus, it is desirable that the CPMAS equipment remain efficient over a wide range of transmission system configurations and be easily adaptable to configuration changes.

Thus, the key requirement for the CPMAS system hardware is flexibility. Flexibility in hardware is met by a combination of modularity and commonality Modularity implies a structure which may be altered easily and efficiently by the addition and/or deletion of self-contained modules which are designed to perform a given function or combination of functions. Commonality implies a structure which may be altered easily and efficiently by altering the functions performed by the modules which make up the structure. This, in turn, implies programmable hardware, with the functions determined by a sequence of control words contained in the program.

7.3.2 Hardware Designs and Recommendations

The CPMAS system design as described in Sections 7.1 and 7.2 requires four CPMAS units which, in various configurations and combinations, satisfy the CPMAS system requirements for the station and nodal levels of the DCS SYSCON hierarchy. These are the CPMAS-NCS, the CPMAS-D unit, the Station Control Position and the Communications Interface Set (CIS). The following paragraphs discuss conceptual hardware designs which realize the functional requirements for these units, as well as meeting the key design requirement of flexibility.

7.3.2.1 CPMAS-NCS

The CPMAS-NCS performs the data gathering, processing and storage for the nodal area of responsibility. It also provides the Nodal Control Position man-machine interface. A conceptual block diagram of the CPMAS-NCS is shown in Figure 7-7. The primary hardware modules of the CPMAS-NCS are the communications interface devices, the communications pre-processor(s), the CPU, program and data memory, mass memory, VDU, keyboard and hard copy unit.

The communications interface devices mate the CPMAS-NCS to its various full duplex asynchronous serial communications channels. These include some number of dedicated telemetry chanels (up to eight, depending upon the size of the nodal area) to subordinate stations, one TCCF CNCE interface, one

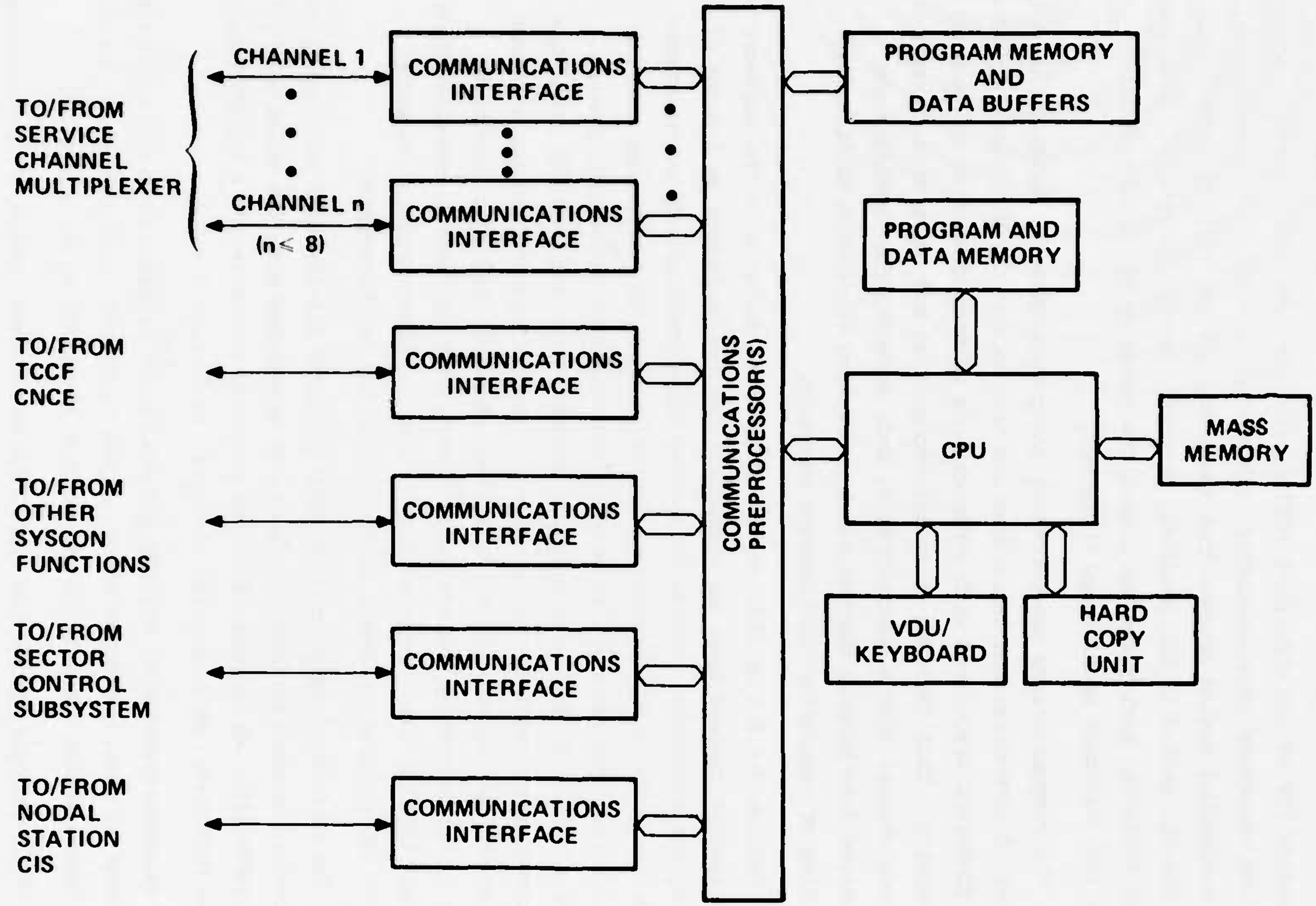


FIGURE 7-7. CPMAS-NCS CONCEPTUAL BLOCK DIAGRAM

interface for as yet undefined SYSCON functions, one interface with sector, and one interface (non-telemetry) with the nodal station CPMAS equipment. The conceptual design assumes that these devices are full duplex and can perform bit serial to bit parallel, character serial conversion, generate or check character parity and can signal the presence of (receive mode) or need for (transmit mode) a new character.

The communications pre-processor (or pre-processors, depending upon the number of communications interfaces and the maximum traffic load) performs the functions associated with communcations channel character and message processing. This includes character recognition and collection, communications channel status determination, and, assuming that messages are formatted into blocks, message block processing (including block parity checking or generation) and message assembly.

Section 7.4.2.1 of this report contains an analysis of the software requirements imposed upon the communications pre-processor as a means of sizing the equipment required to realize the communications pre-processor functions. The analysis includes the calculation of processing time per input/output character for three different types of processing systems. These are an eight-bit microcomputer (based on the Intel 8080A), a 16-bit microcomputer (based on the DEC LSI-11), and a 16-bit minicomputer (based on the DEC PDP-11/34). Once the minimum required character throughput rate is determined by the analysis of such areas as maximum communications channel traffic load, average traffic load and maximum system response times, the optimum equipment configuration may be determined.

The Central Processing Unit (CPU) performs all the data processing (as opposed to message processing) functions associated with the nodal area of responsibility, as determined by the programs stored in the program memory. These functions are enumerated in detail in Section 7.4.2.1.

Characterization of the CPU and associated program, data and mass memory in terms of size, execution and/or access times and instruction set, requires a software sizing analysis of the various functions to be performed.

This analysis yields the types of instructions, number of instructions and amount of data storage required to implement each function. This

information, in conjunction with system-derived real-time processing constraints, is then used to characterize the processing equipment required. Such a task, being necessarily implementation oriented, is beyond the scope of this study. Also, the DCS digital transmission system itself is insufficiently defined at this time to derive accurate real-time processing constraints.

The last remaining item of the CPMAS-NCS to be considered is the man-machine interface, consisting of at least one Visual Display Unit (VDU), keyboard, and hard copy device. It is anticipated that the intelligence required by the keyboard/VDU device may be no more than that required by a TTY unit by using the capabilities of the CPU. The VDU should, however, be capable of displaying forms as an aid in semi-automated report generation.

7.3.2.2 CPMAS-D Unit

The CPMAS-D Unit is the MAS element which performs the performance monitor and assessment function for the DCS digital transmission equipment at a station. This includes monitoring binary alarm and status points, counting and processing radio/multiplexer frame error pulses, processing of radio analog parameters, the employment of performance assessment techniques and the execution of control and self-test routines.

A conceptual block diagram of the CPMAS-D unit is shown in Figure 7-8. The basic structure of the CPMAS-D consists of hard-wired modules which allow the CPMAS-D unit to read the status of the binary monitor points, detect and count frame error pulses, calculate frame error rate independently for each frame error pulse monitor point, measure analog parameters, execute performance assessment algorithms and execute control functions under control of the CPU.

The analog and digital multiplexer addresses are provided by the CPU under control of the scan program. This is the means by which data is input to the CPU for analysis. The pulse counter and performance assessment circuitry run independently of the CPU. Results of the most recent calculation for each measurement are held in storage registers for examination by the CPU at the appropriate time.

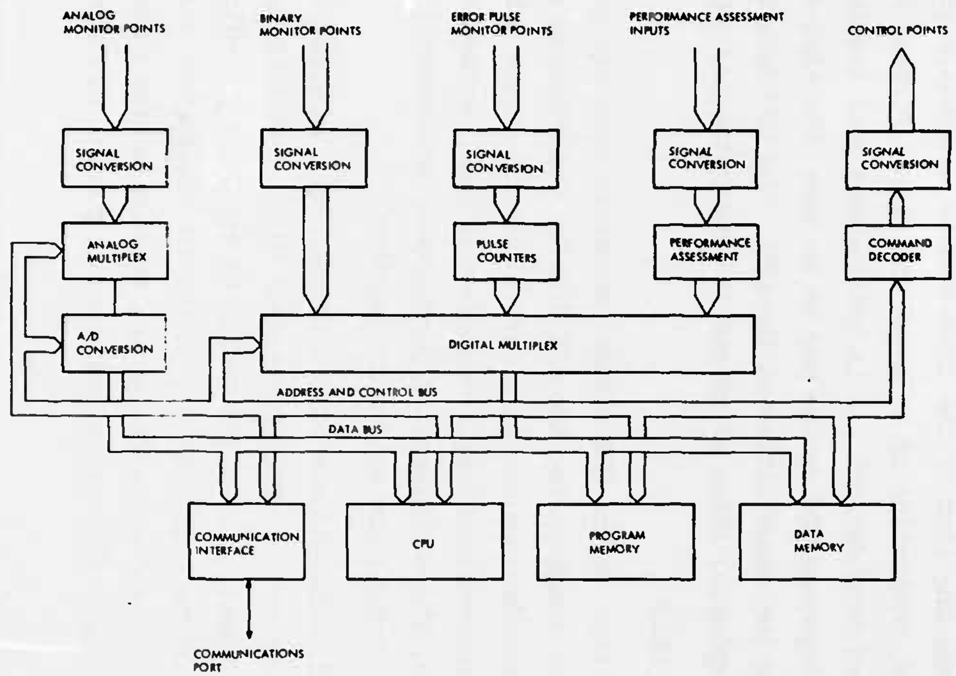


FIGURE 7-8. CPMAS-D UNIT CONCEPTUAL BLOCK DIAGRAM

The communication interface is full duplex, asynchronous and runs at a data rate of 150 baud. The communications interface device performs bit serial to bit parallel, character serial conversion, generates or checks character parity, and can signal the presence of or need for a new character.

All other CPMAS-D functions are performed by the CPU in conjunction with the program and data memory. This includes binary alarm change-of-state detection, error rate threshold comparison and alarming, analog parameter threshold comparison and alarming, performance assessment parameter threshold comparison and alarming, fault message generation, message processing and self-test. It is estimated that an eight-bit MOS microprocessor for the CPU with 8K bytes of ROM program memory and 8K bytes of RAM data memory is sufficient to handle at least 4096 binary points, 256 analog points, 256 frame error points and 32 performance assessment points. An 8-radio DCS DRAMA nodal station configured as shown in Figure 7-9 as Node Station ABC, which is the largest DCS digital transmission system model station, contains 2256 binary points, 156 frame error points, 224 analog points and 16 performance assessment points. Thus, a single CPU, memory and communication interface configuration, which may be packaged on two or three logic cards, forms a common hardware module for any CPMAS-D configuration. The CPMAS-D configuration itself is determined by the numbers and mix of monitor and assessment points at a station, which determines the number of CPMAS-D hard-wired modules required.

Analyses were performed on the conceptual CPMAS-D unit to determine in a general way how sensitive this model is to varying DCS digital transmission equipment configurations. The results of the analyses are shown in Figures 7-10 through 7-13. Figure 7-10 represents the relative cost of monitoring binary, analog and error pulse points. The Y-axis intercept point is determined by the cost of the common hardware which includes the CPU, program memory, data memory, the communications interface device, power supplies and the mechanical package.

It is intuitively obvious that the error pulses are the most expensive to monitor, since each point requires a dedicated binary counter. What is not obvious, however, is that binary points are more expensive to monitor than analog points. This phenomenon is due to the nature of the signal

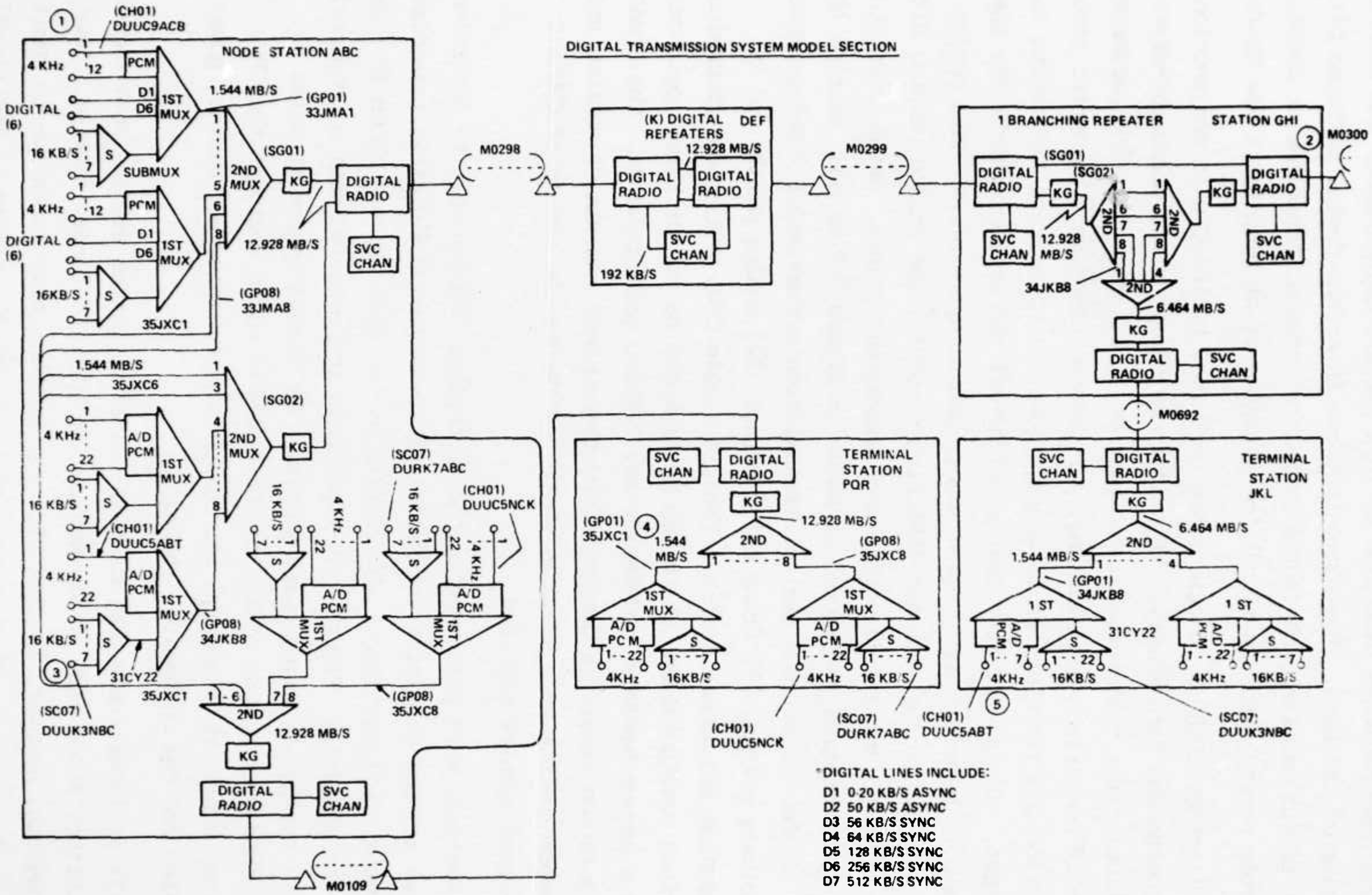


FIGURE 7-9. DCS DIGITAL TRANSMISSION SYSTEM MODEL

CPMAS-D COST VS. MONITOR POINT QUANTITY

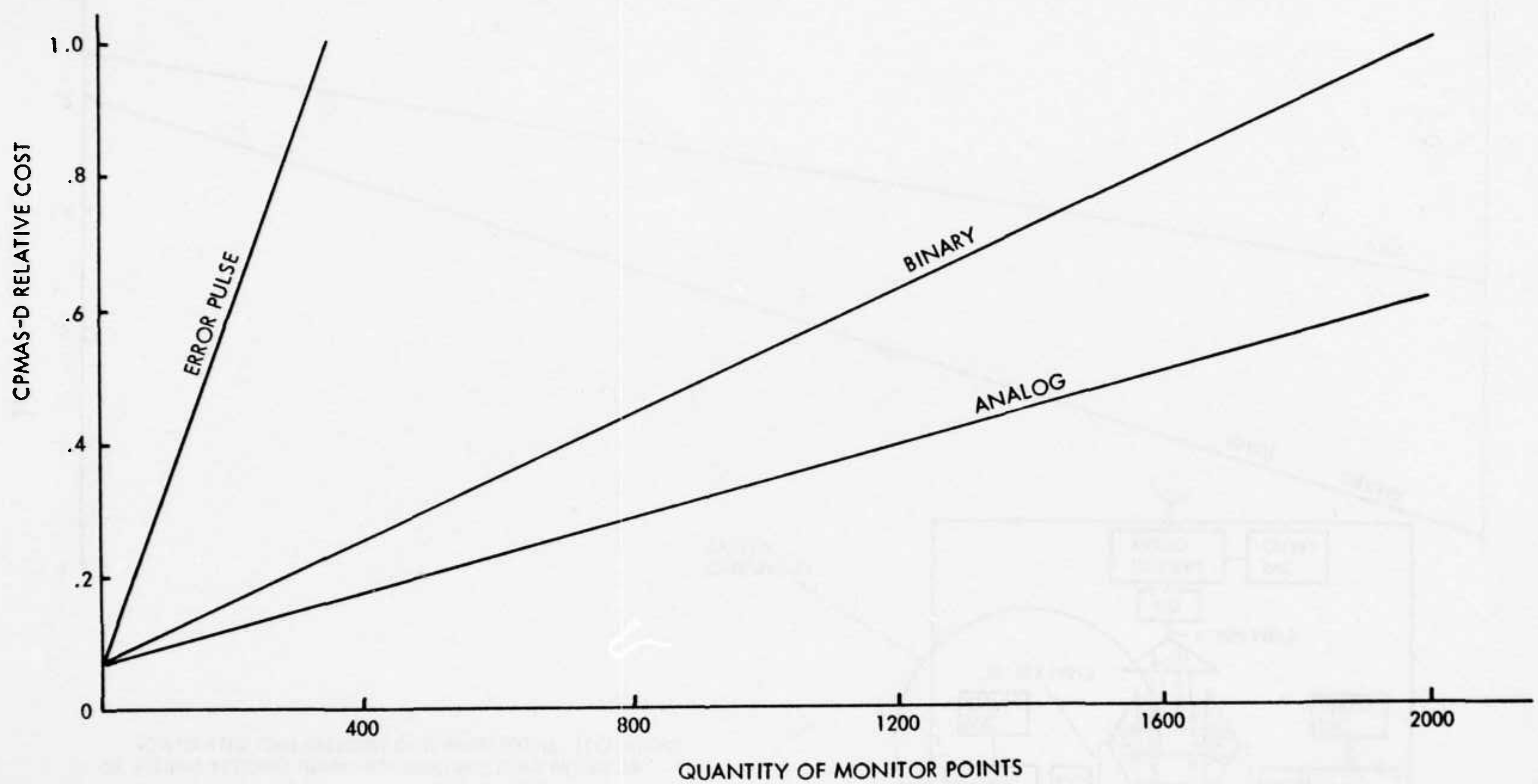
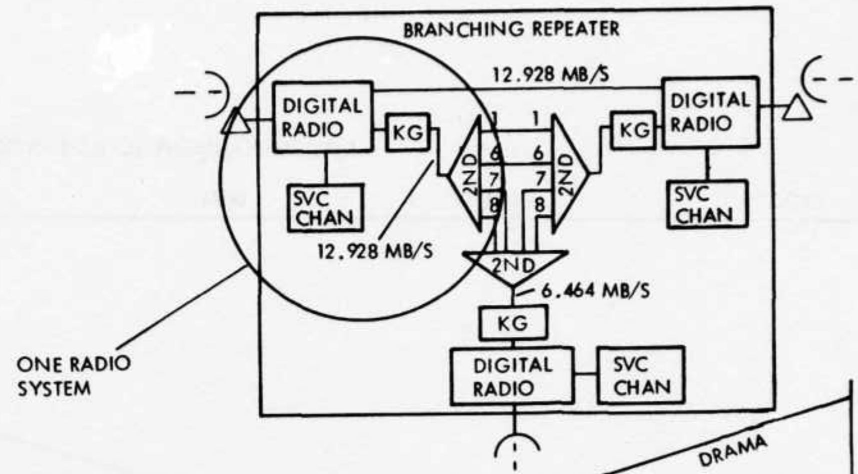


FIGURE 7-10. CPMAS-D COST VS. MONITOR POINT QUANTITY

NOTE (1) BR. REPEATER RADIO SYSTEM: 1 RADIO
1 KG-81 (EXCL. FKV)
1 SECOND LEVEL MUX
1 SVC CH MUX
(2) SIZING ASSUMES USING ALL EXISTING EQPT MONITOR POINTS PLUS ONE PERFORMANCE ASSESSMENT TECHNIQUE



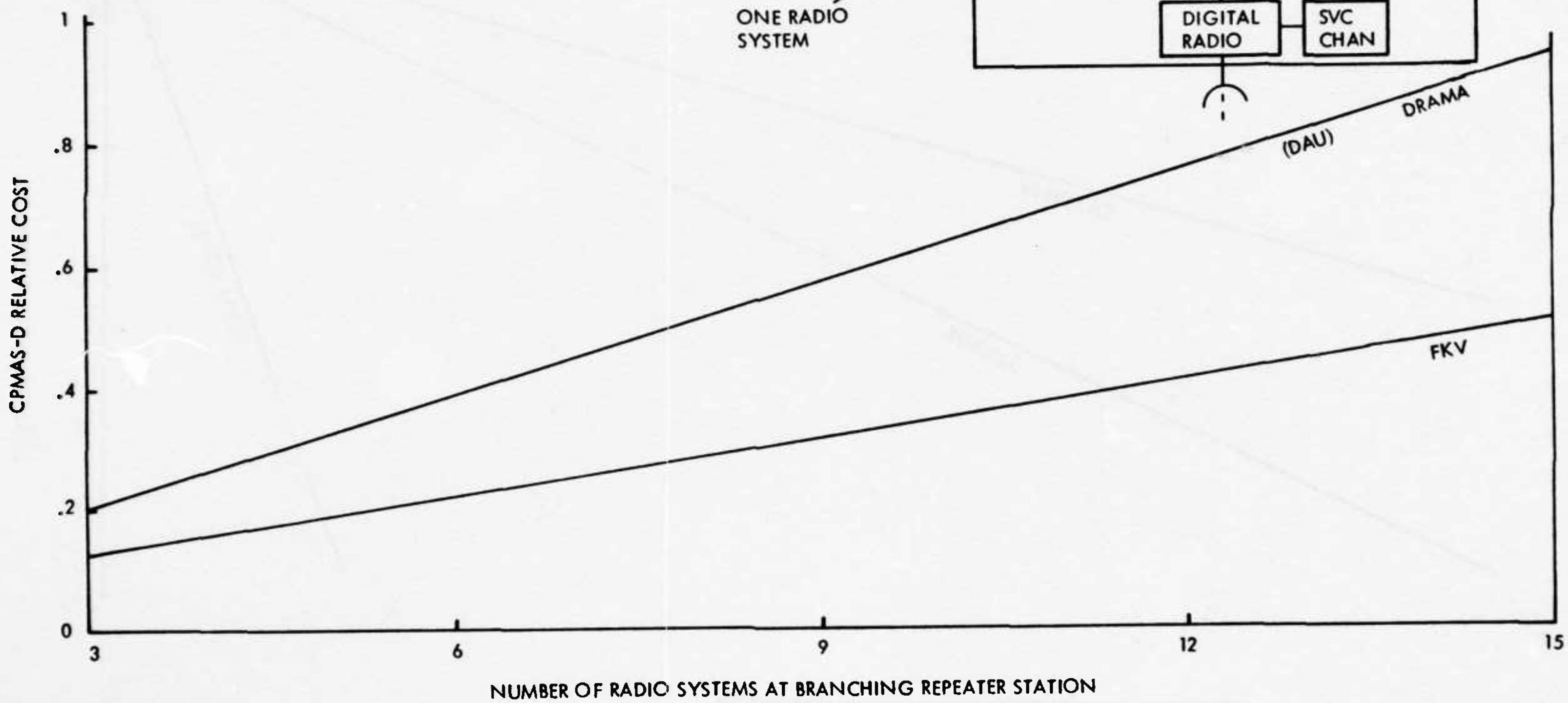


FIGURE 7-11. CPMAS-D BRANCHING REPEATER COST

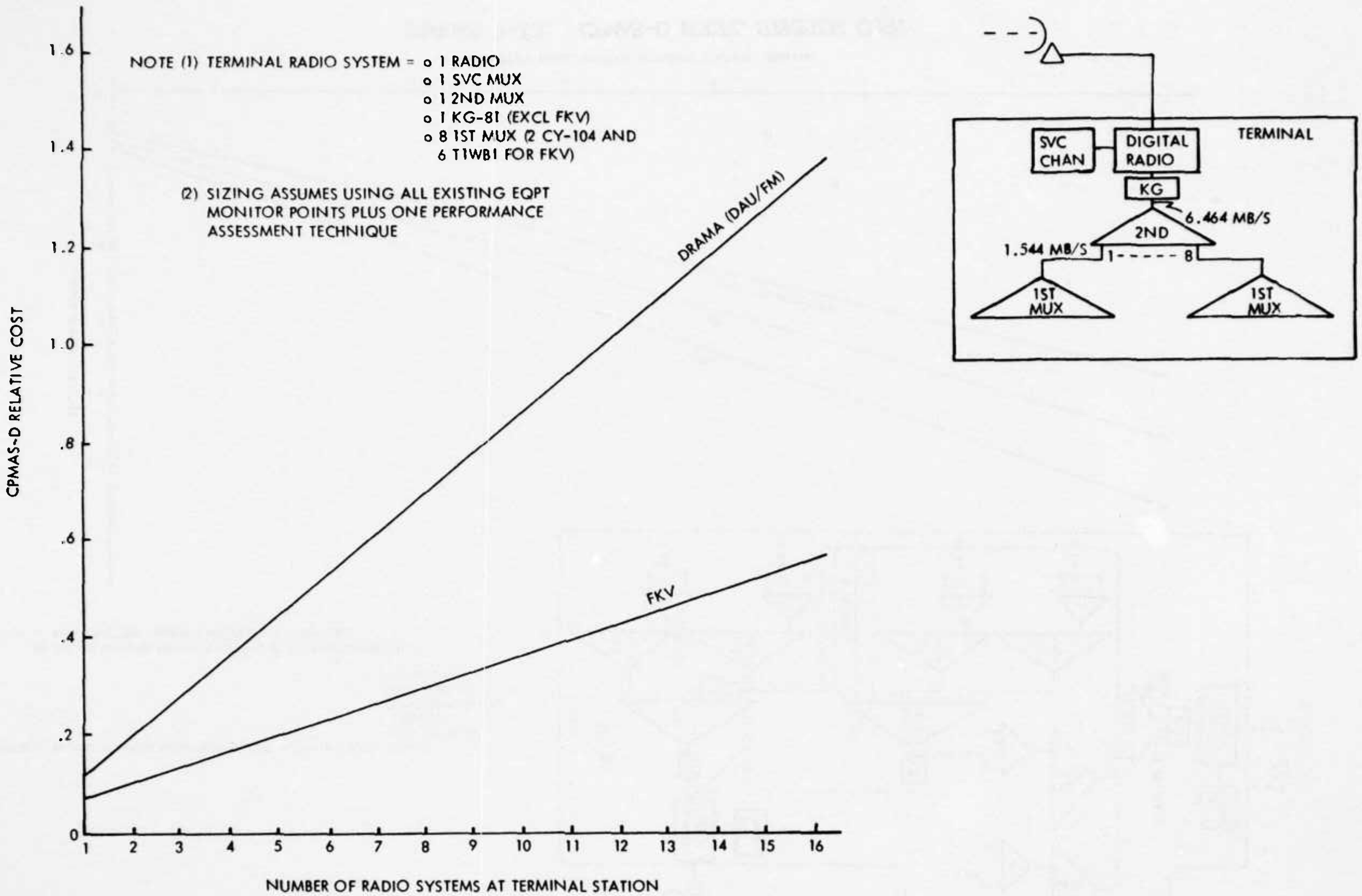
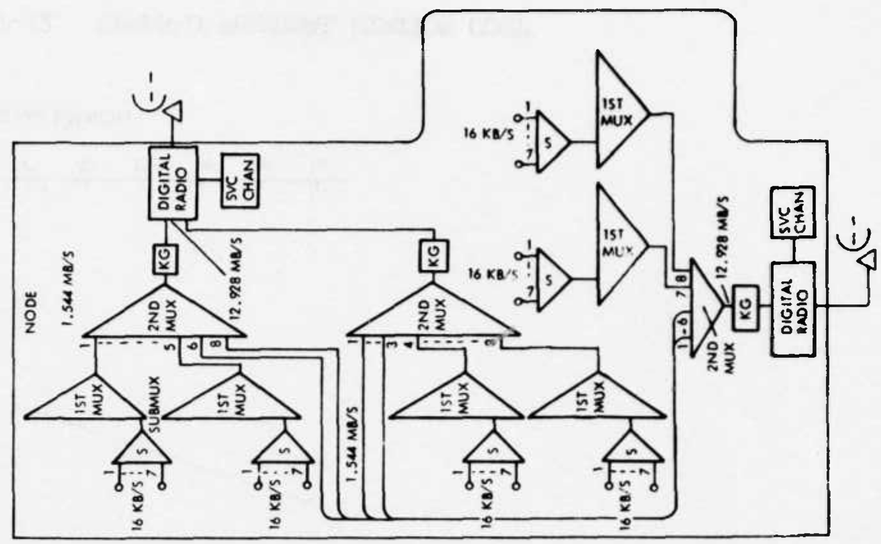


FIGURE 7-12. CPMAS-D TERMINAL STATION COST

NOTE (1) NODAL STATION RADIO SYSTEM (50% TERMINATIONS) = 2 RADIOS
2 SVC CH MUXS
3 KG-81s
3 2ND LEVEL MUXS
12 1ST LEVEL MUXS
12 SUBMUXS

(2) SIZING ASSUMES USING ALL EXISTING EQPT MONITOR POINTS PLUS ONE PERFORMANCE ASSESSMENT TECHNIQUE



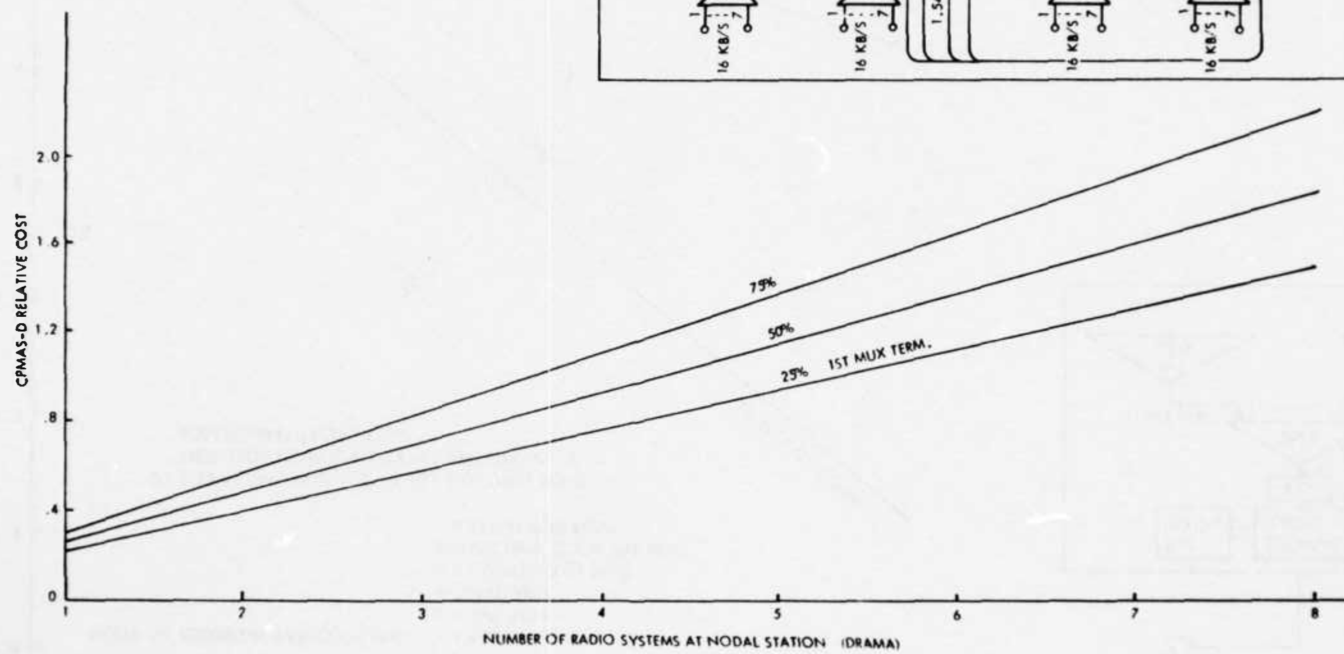


FIGURE 7-13. CPMAS-D NODAL STATION COST

conversion circuitry. In the hypothetical implementation, it is assumed that the binary monitor points require set-reset flip-flops to provide a contact closure debounce function, and that the contacts provided in the transmission equipment are form C to allow connection as either normally closed or normally open. This means that each binary point requires a three-wire input to the signal conversion circuitry versus an assumed single wire input to the analog point signal conversion circuitry. Therefore, more inputs and consequently more circuit cards are required to implement the binary signal conversion function than the analog signal conversion function for an equal number of monitor points.

Figure 7-11 shows the relationship between CPMAS-D relative cost and the size of a branching repeater station for a DRAMA, a DAU-FM and an FKV transmission system. For a single radio system, as identified by the inset figure and the legend, the DRAMA implementation yields 102 binary monitor points, 6 frame error monitor points and 28 analog monitor points. The DAU-FM implementation yields 123 binary monitor points, 5 frame error points and 4 analog monitor points. The FKV system includes 31 binary monitor points, 0 error pulse points and 3 analog points. Each of the systems includes 2 performance assessment points per radio system, and 14 site alarm points. The radio system configurations are based on Government furnished information and DRAMA specifications. The monitor points are those existing points mentioned in the DRAMA specifications and the ATEC Digital Adaptation Study Final Report.

Figure 7-12 shows the CPMAS-D cost/size relationships for an 8-group terminal station. The DRAMA station contains 166 binary points, 14 error pulse points and 28 analog points. The DAU-FM station yields 187 binary points, 13 frame error points and 12 analog points. The FKV station has 38 binary points, 0 frame error points and 10 analog points. There are 2 performance assessment points for each radio for each of the three implementations. The inset shows the equipment relationship for one radio system.

Figure 7-13 shows the CPMAS-D cost/size relationships for a DRAMA Nodal Station of variable size and first level multiplex terminations. The inset depicts a single radio system with 50% terminations. For 25% terminations, the number of first level multiplexers and submultiplexers are halved. For

75% terminations, the number is multiplied by 1.5. For 25%, a single radio system has 396 binary, 27 error pulse and 56 analog points. For 50%, it has 564 binary, 39 error pulse and 56 analog points. For 75%, the radio system contains 732 binary, 51 error pulse and 56 analog points. One radio system also includes 4 performance assessment points independent of the termination percentage.

7.3.2.3 Station Control Position

The Station Control Position is an intelligent CRT terminal with hard copy generation capability. As shown in Figure 7-14, the Station Control Position elements include an ASCII Keyboard input device which also includes special function keys for the efficient execution of common routines, an 80 character/line 24 lines/page visual display unit, hard copy device, program memory, data memory, bulk memory, a full duplex asynchronous communications interface device and a microprocessor-based intelligent controller. The Station Control Position allows the station controller to receive status and performance information from his local station, and to communicate with the CPMAS-NCS and the nodal controller. Section 7.4.2.3 of this report contains a detailed description of the funtions performed by and the inetrrelationships between the elements of the Station Control Position.

7.3.2.4 Communications Interface Set

The Communications Interface Set (CIS) provides the communications interface between the CPMAS-D unit and the Station Control Position at a station, between each CPMAS-D unit and its associated CPMAS-NCS, and between each Station Control Position and its NCS. The communications interface function involves message format, message protocol and error control functions. Section 7.4.2.4 contains further definition of the communcations interface functions and the requirements imposed upon the CIS by these functions.

A conceptual block diagram of the CIS is shown in Figure 7-15. The major modules of the CIS are three communications interface devices, the CPU, and program and data memory. The communications interface devices handle full duplex, asynchronous communications, and perform bit serial to bit parallel, character serial character format conversions as well as generating

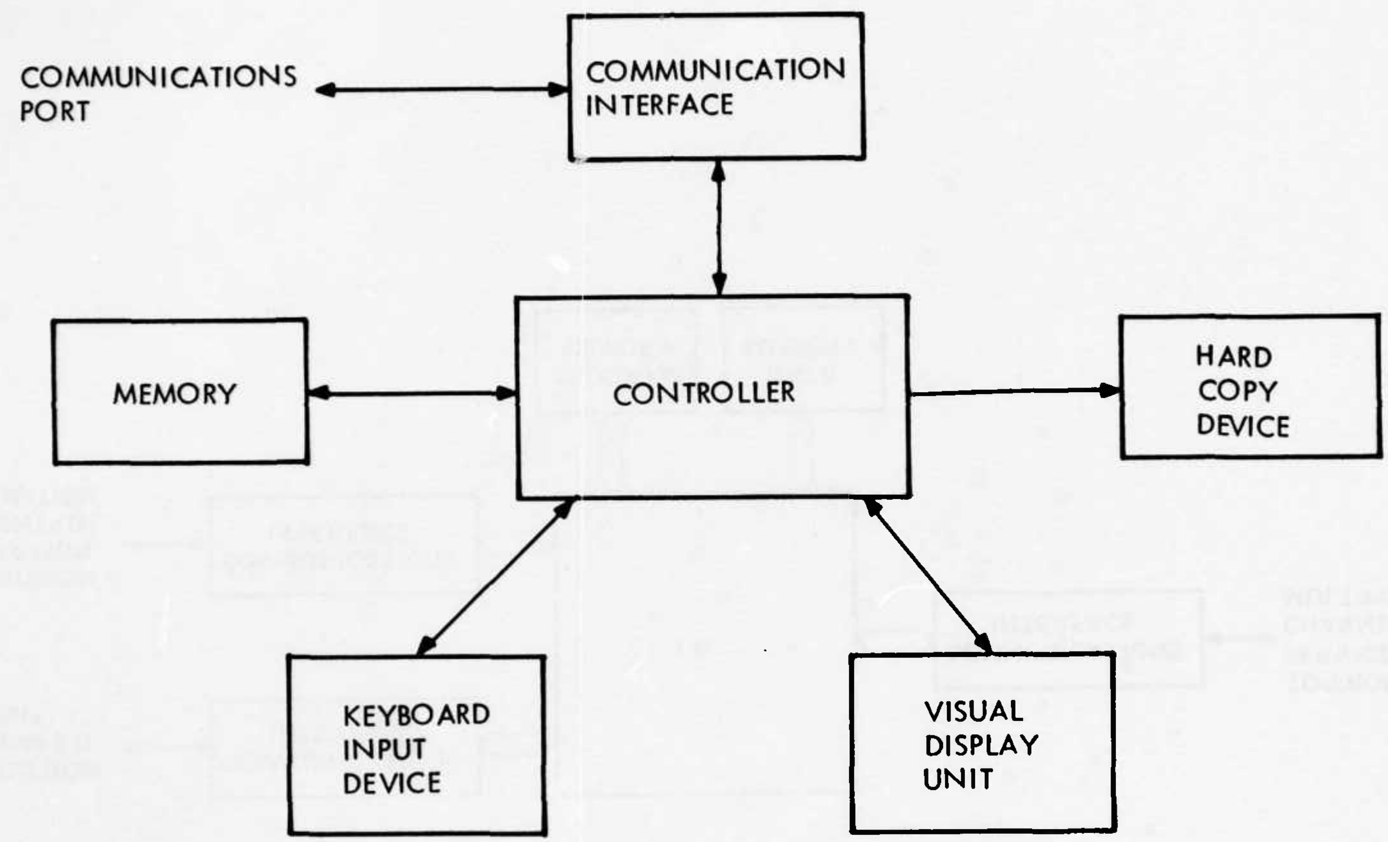


FIGURE 7-14. STATION CONTROL POSITION CONCEPTUAL BLOCK DIAGRAM

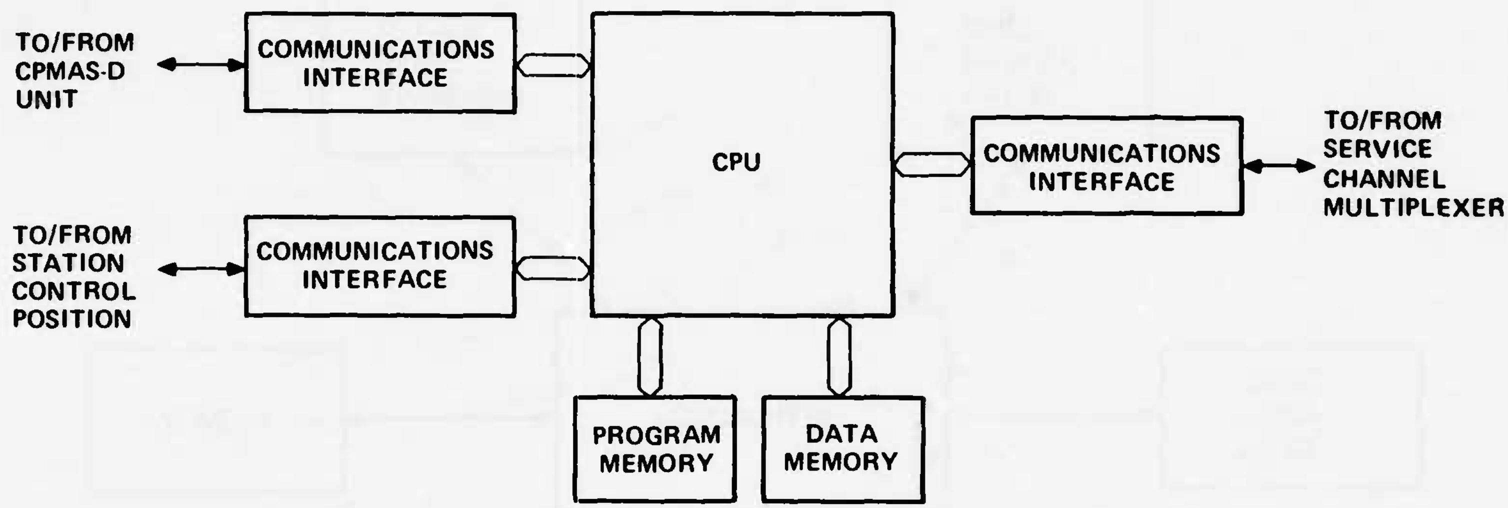


FIGURE 7-15. CIS CONCEPTUAL BLOCK DIAGRAM

or checking character parity. The CPU, in association with its program and data memory, performs all other functions associated with the CIS, as detailed in Section 7.4.2.4.

7.4 CPMAS Software Description

The purpose of this section is to identify and functionally describe the software required for monitoring and assessing the DCS digital transmission system within the scope of this study. A Digital Transmission System Model has been provided as a framework for this study. This model provides a digital transmission system which includes a nodal control area, a large nodal station, terminal and repeater stations, a satellite terminal interface and several radio system alternatives.

7.4.1 Introduction

The CPMAS software system is hierarchical by nature. The system is made up of four functional units:

a) CPMAS-NCS software which performs the nodal control CPMAS functions and processing for nodal controller displays and controls. This function is the nucleus of the CPMAS system.

b) CPMAS-D software controls the monitoring of performance and assessment parameters of the digital transmission equipment at a station.

c) Station Controller Position software primarily provides the means by which the station controller can monitor and control the equipment at the station.

d) Communications Interface Set (CIS) software coordinates communication interface among CPMAS/ATEC units at the station, the Station Controller Position and Nodal Control Subsystem.

The CPMAS-NCS is the nucleus of the CPMAS function. The Nodal Control Processing System software coordinates reception and request of status and performance assessment data from the CPMAS-D units of all stations within the Nodal Area. In addition, the NCS software controls the fault

detection/isolation and performance assessment function for the nodal area. The software resident at the NCS also formats the displays used in status and alarm notification. Similarly, reports for system dissemination are formatted and generated both automatically and with operator intervention at the NCS. The software also maintains CPMAS parameter histories and data bases for the nodal area. The NCS software also coordinates CPMAS data transfer and message communication between the station controls within the nodal area and the sector control.

The data gathering function of the CPMAS system is provided by the CPMAS-D subsystem. The software resident in the CPMAS-D coordinates and controls the data monitor function. It performs exception processing to determine state changes, and it coordinates status data transmission to the respective nodal control position and station control position. In addition, the CPMAS-D software performs effectivity processing for requests from the NCS and the respective station control positions.

The data transfer between the detection and measurement elements of the CPMAS system, the station control position, and the nodal control position is coordinated by the CIS subsystem. The software resident in the CIS controls this function. In addition, the CIS software provides the protocol processing necessary for inter-site communication.

The station control function, like the nodal control function, is under software control. The software resident at the station control will control the man-machine interface for the CPMAS function at the station. This is the means by which the station controller can operate in the stand alone mode in the event of a CPMAS-NCS failure. Additionally, the software will coordinate traffic data between the station control position and the CIS.

Each of these CPMAS software functions is described in detail in the sections to follow.

7.4.2 CPMAS-NCS Software Functional Description

The CPMAS-NCS functional requirements consist of five major areas:

a. Man/Machine Interface
b. Fault Isolation
c. Performance Assessment

d. Parameter History/Report Generation

e. Event Logging

f. Communication Interface

The Nodal Status Display function consists of the processing requirements necessary to monitor and display the network status. This includes the status of all sites, paths, and equipments within the nodal area of responsibility.

The CPMAS Fault Isolation function includes the software to comply with the fault detection/isolation requirements. Simply stated, the requirement is reliable isolation and identification of faults.

The Performance Assessment function includes the parameter calculation, assessment algorithms, and data analysis necessary to assess the performance of both individual system components and the network as a whole.

The Parameter History function incorporates the results of fault isolation and performance assessment functions as well as raw data histories to trend the network and equipment characteristics.

Event logging will provide statistics to be incorporated in required NCS reports. A more detailed event log or transaction journal will provide a means for system backup and recovery/restart capabilities.

The Communication Interface function provides the Nodal Control Subsystem with the capability to transfer/receive information to/from all interfacing CPMAS stations. This function is identical to the Communication Interface software function performed at all CPMAS stations.

The basic functional requirements as stated above are allocated as shown in the CPMAS operational software family tree Figure 7-16. Not shown in the family tree is the off-line development, test, and evaluation support software. These include the assembler/compiler, loaders, debug programs and other off-line computer software

7.4.2.1 NCS Communication Interface

The total number of functions presented in the previous section require an investigation of a configuration which will permit the NCS to perform efficiently its myriad of functions. A commonly used configuration for

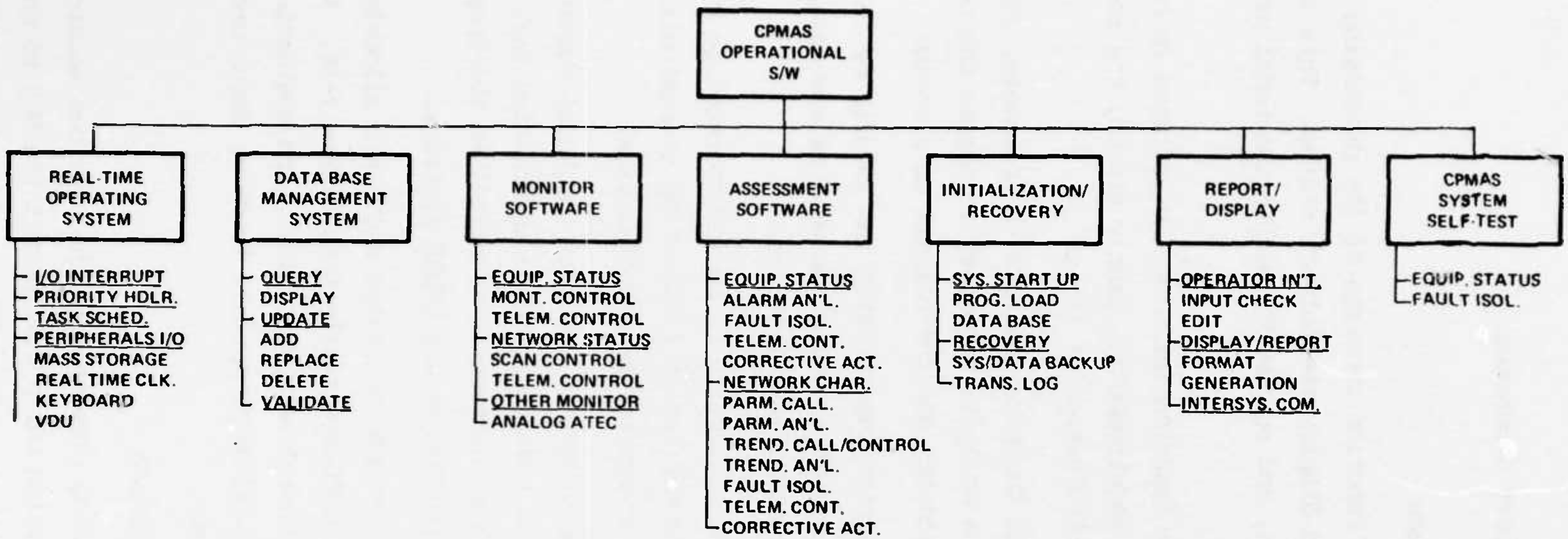


FIGURE 7-16. CPMAS OPERATIONAL SOFTWARE FAMILY TREE

AD-A047 207 GTE SYLVANIA INC NEEDHAM HEIGHTS MASS ELECTRONIC SYS--ETC F/G 9/6
AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL--ETC(U)
OCT 77 F30602-76-C-0433

UNCLASSIFIED RADC-TR-77-327 NL

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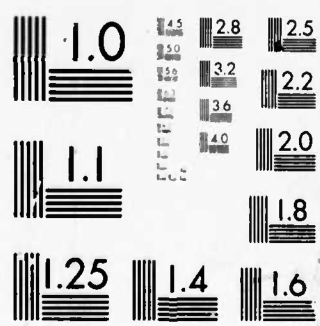

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

communication systems is the tandem concept as shown in Figure 7-17. In this configuration the software functions (system functions) are allocated such that the front end processor performs all the channel coordination procedures. These involve, at a minimum, performing the character (or character group) recognition, block building, block processing, protocol processing and all telemetry channel I/O. At the conclusion of this required processing, the amount of additional processing which can be performed by the front end processor depends on the traffic density, processing speed and storage capacity available to the front end processor. Obviously, the more processing the front end processor can perform to approach a 50-50 split of functional requirements, the more efficient the entire system will be, and the greater the growth potential for the system in the future. The configuration presented above shows only one (1) front end processor interfacing with the central processor; however, the possibility exists that a more realistic configuration would be as shown in Figure 7-18. This configuration provides n front end processors, each performing identical functions for a mutually exclusive subset of the total number of communication links (sites).

The following paragraphs present a software timing analysis with the objective of determining the number of Front End processors required for the above described configuration. This analysis compares "typical" micro and mini computer systems.

The Front End Processor of the Nodal Control Subsystem is responsible for providing the communication interface between the Nodal Control Subsystem and all other interfacing CPMAS sites. Figure 7-19 depicts a top level software family tree diagram which will serve as the basis for the subsequent core and timing analysis. For purposes of this analysis, Figure 7-19 is further subdivided into a sequence of unique subfunctions, shown in Table 7-2, which must be performed by the Front End Processor to accomplish the desired communication interface task.

For purposes of this analysis, each of these subfunctions has been analyzed to estimate the required number of instructions and execution time requirements. A variety of possible equipment configurations were used in the analysis. The major equipment configuration considered included

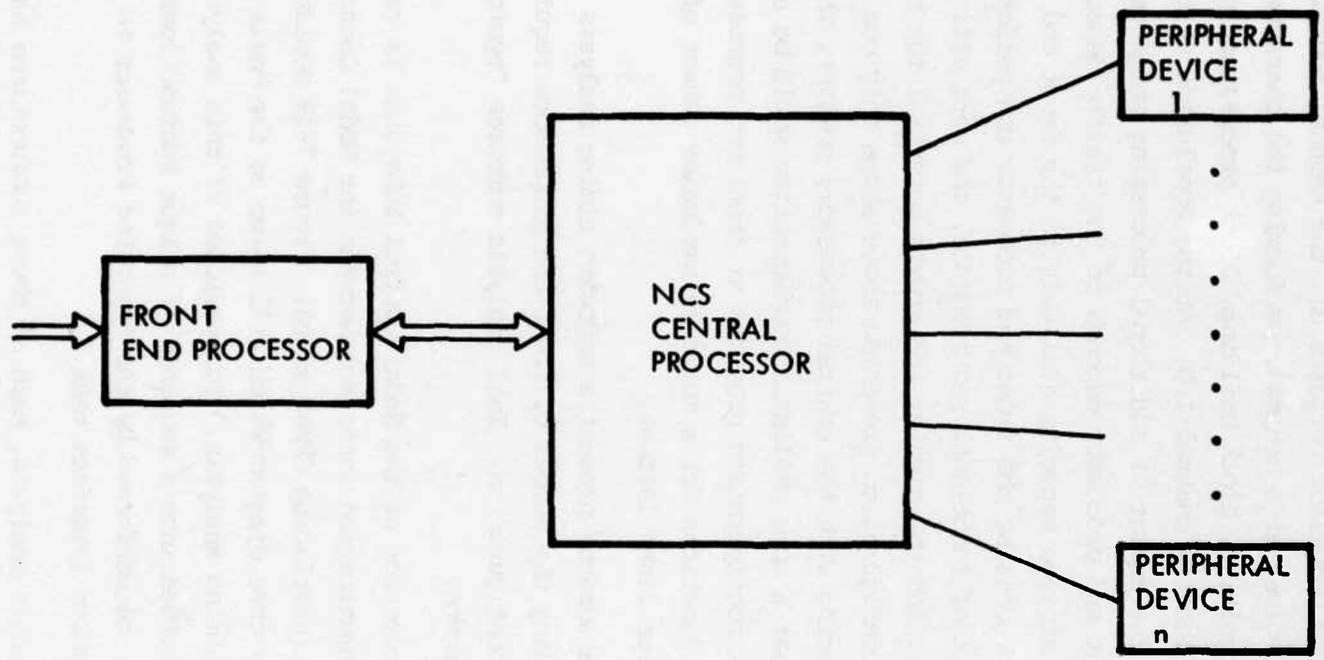

FIGURE 7-17. NCS FRONT END PROCESSOR CONFIGURATION 1

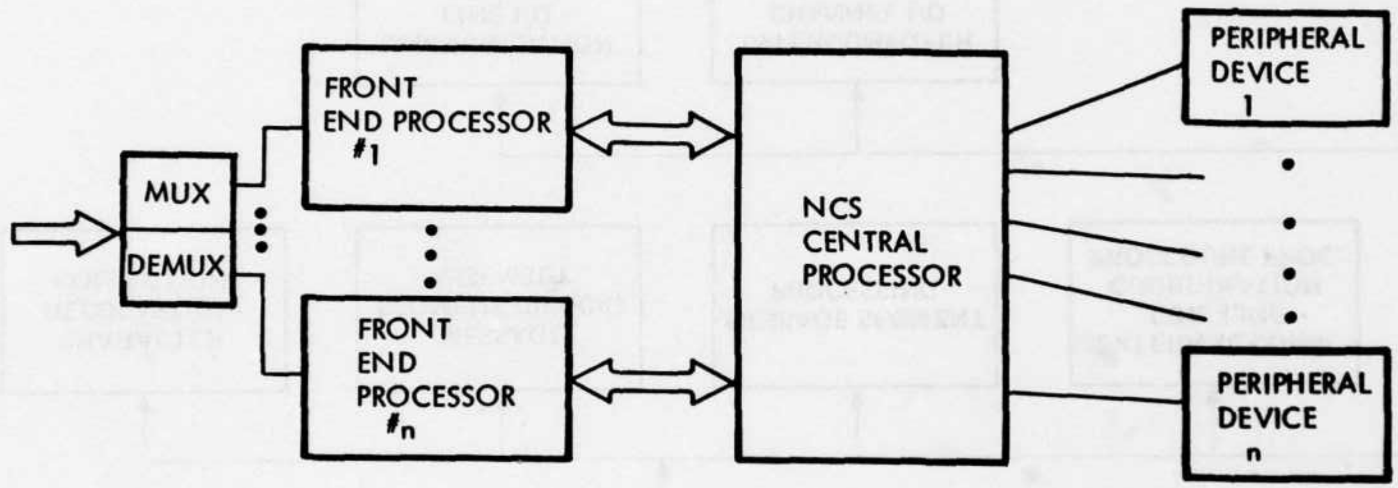

FIGURE 7-18. NCS FRONT END PROCESSOR CONFIGURATION 2

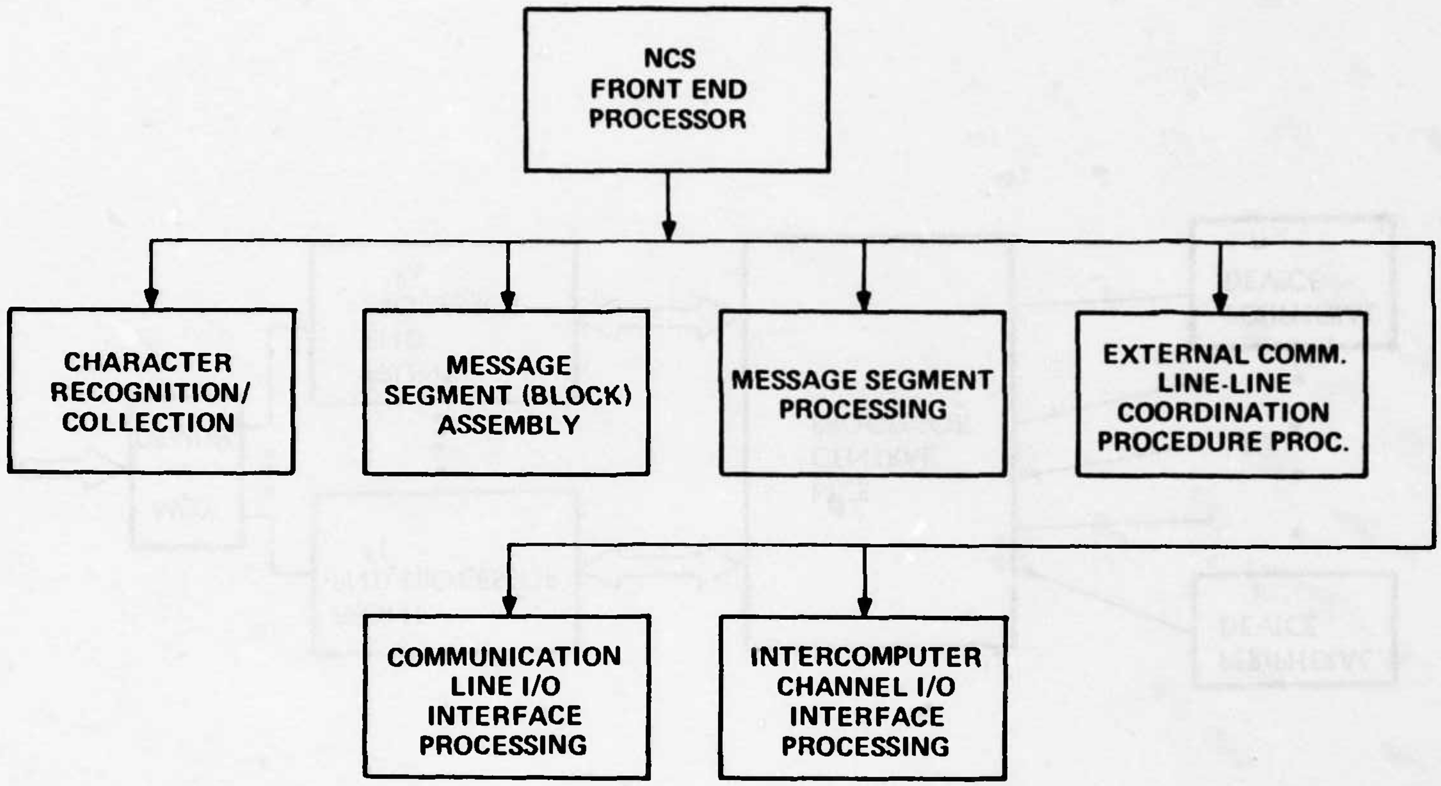

FIGURE 7-19. NCS FRONT END PROCESSOR SOFTWARE FUNCTIONS

TABLE 7-2. NCS FRONT END PROCESSOR SUBFUNCTIONS

- System Initialize
- Buffer Management For Blocks
- Compute Block Parity on Received Data
- Input A Character
- Assemble Collected Characters Into Blocks
- Determine and Prepare Line Coordination Messages as Specified
- Output A Character
- Error Processing
- Self-Test
- Compute Block Parity For Blocks Output To Comm. Lines
- Intercomputer Channel Protocol Processing
- Channel Status Processing

analyzing these software requirements with respect to Direct (Programmed) I/O, Direct Memory Access I/O, and each of these with and without interrupt capability. In addition to the varying system requirement configurations, the analysis will include the same information for typical microcomputer systems (8080A and LSI-11) and a typical minicomputer system (DEC 11/34).

The results of this analysis are presented in Figures 7-20 to 7-22. These figures show the estimated total processing time required per character for the various systems and their equipment configurations versus the resulting throughput processing rate. The throughput rate is defined by Figure 7-23. From Figure 7-20, it is seen that an Intel 8080 with DMA and interrupt capability can perform the front end processor function at a rate of .82 ms per character. This yields a maximum throughput rate of approximately 9680 baud. The results for the Intel 8080 with DMA but no interrupt capability is shown to be .91 ms per character or a maximum throughput rate of approximately 9280 baud. Similarly, when configured with an interrupt capability but no DMA, the Intel 8080 can process a character in 1.36 ms or maintain a maximum throughput rate of approximately 5840 baud. Lastely, an Intel 8080 configured without either DMA or Interrupts would require 1.45 ms per character and have a maximum throughput rate of 5120 baud.

Figures 7-21 and 7-22 provide the estimated results for both a DEC LSI-11 and a DEC PDP-11/34 configuration. It is shown that the highest througput rate for the DEC LSI-11 (with DMA and Interrupts) is 12400 baud. Similarly, the highest througput rate for the DEC 11/34 (with DMA and Interrupts) is 23700 baud.

The following sections describe the software resident in the main NCS processor.

7.4.2.1.2 Executive Software

CPMAS operational software requires a real-time executive architecture. The software must be capable of executing in a multi-task environment. It is imperative that this software be capable of scheduling operator initiated tasks for execution while continuing to automatically schedule those tasks normally scheduled for execution. It must also accommodate a priority

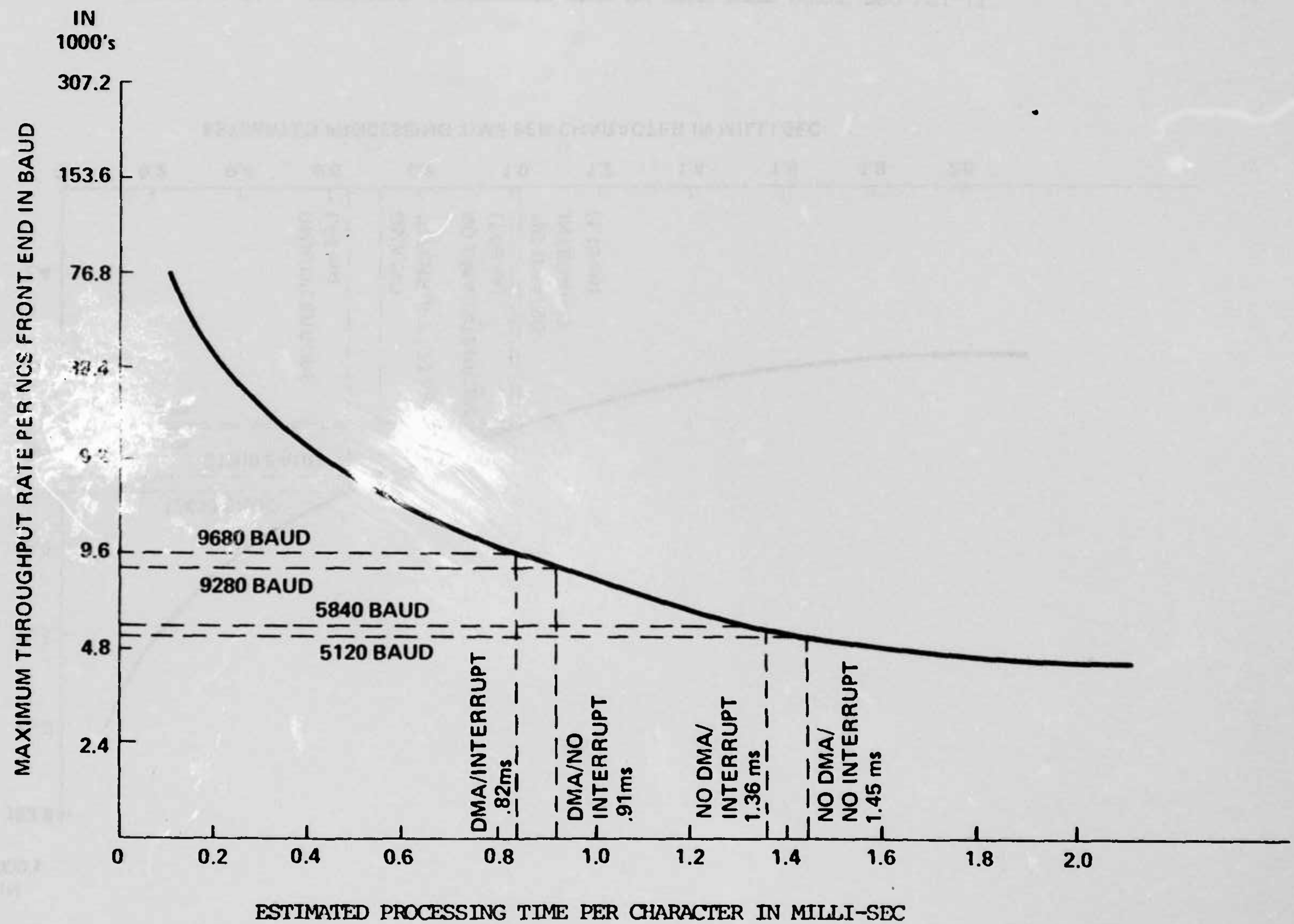

FIGURE 7-20. ESTIMATED PROCESSING TIME VS BAUD RATE USING INTEL 8080

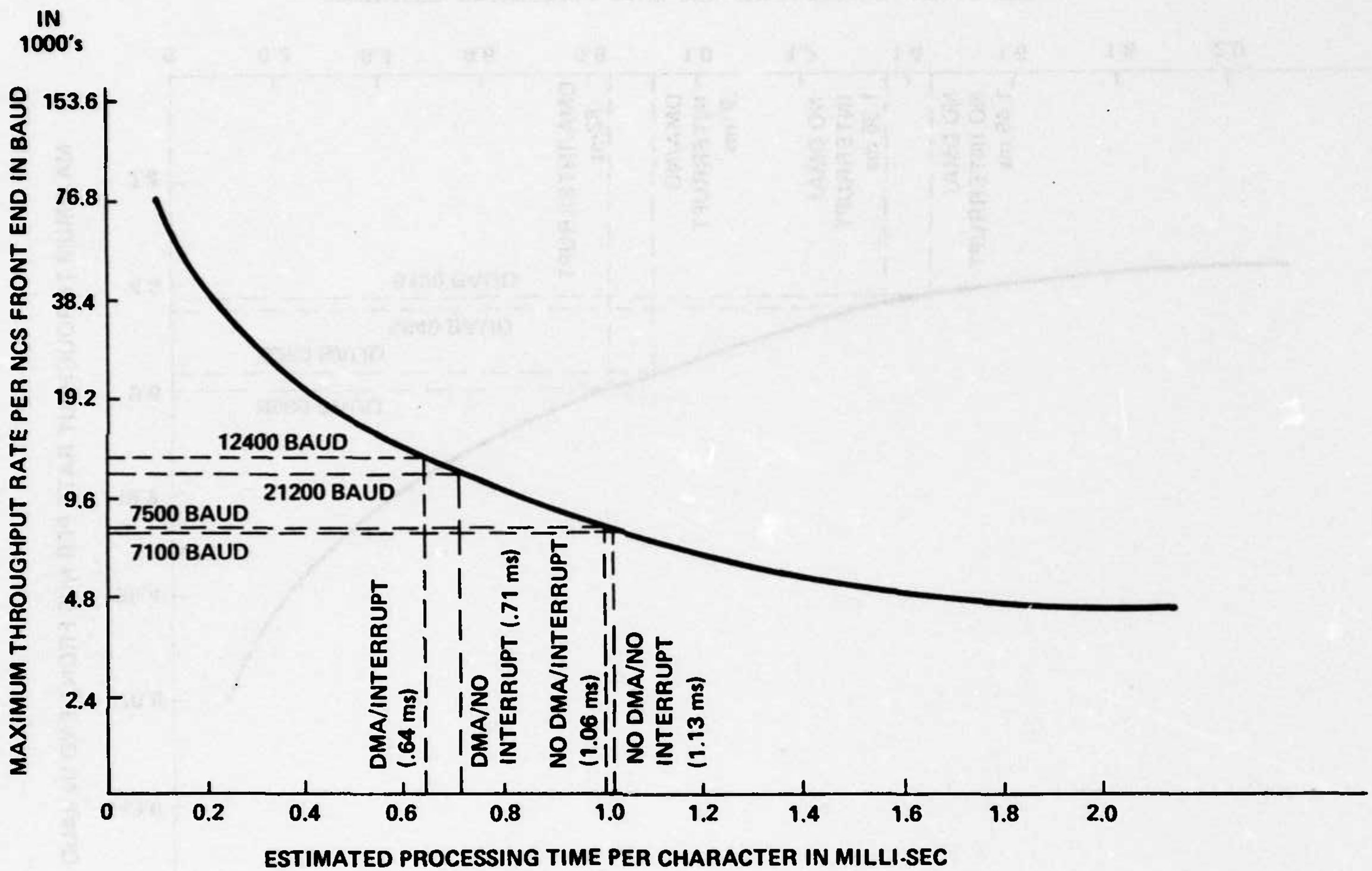

FIGURE 7-21. ESTIMATED PROCESSING TIME VS BAUD RATE USING DEC LSI-11

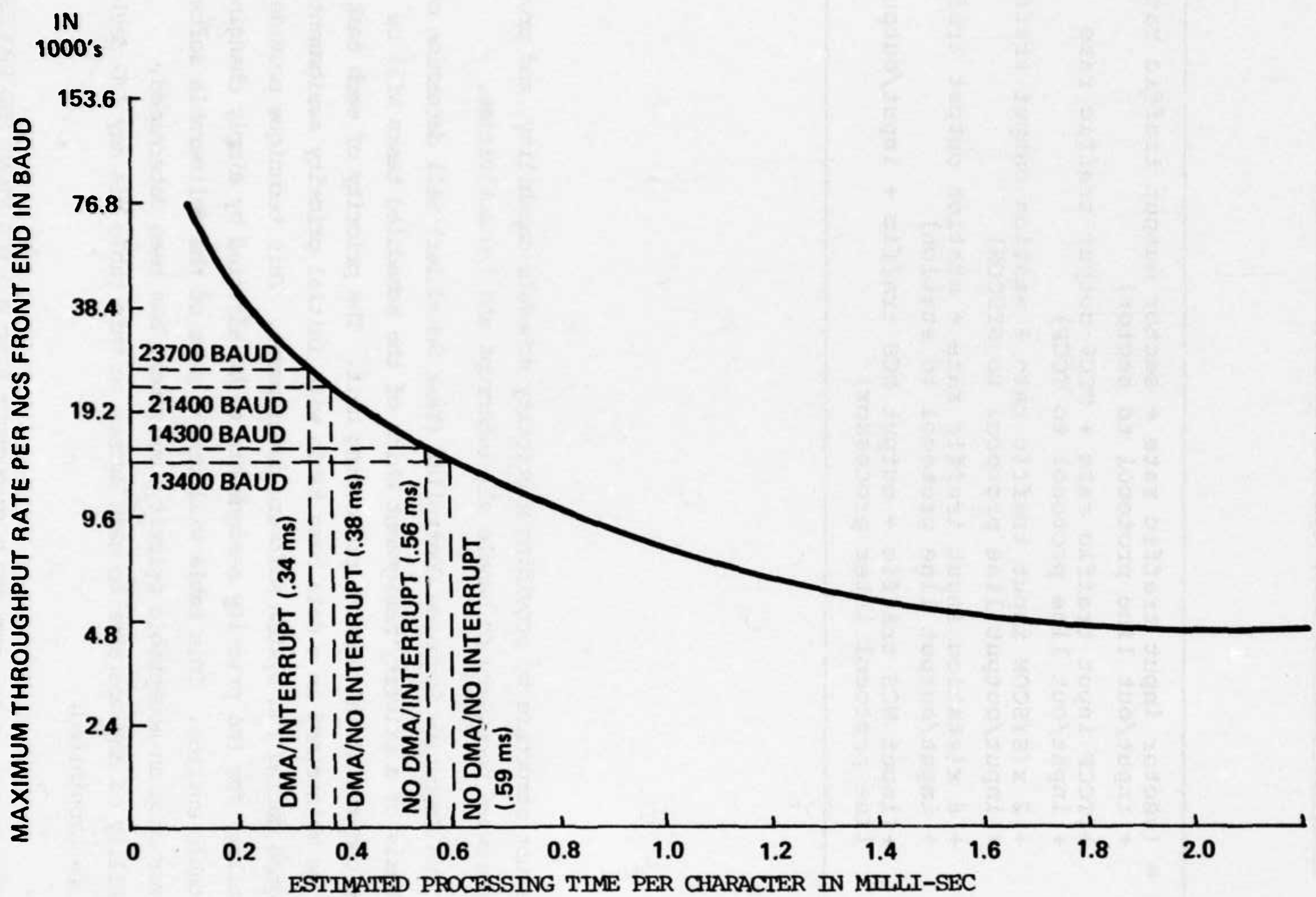

FIGURE 7-22. ESTIMATED PROCESSING TIME VS BAUD RATE USING DEC PDP 11/34

FIGURE 7-23

Total Effective Throughput Rate for NCS Front End Processor

```
RATE = (sector input traffic rate + sector output traffic rate
       + input/out line protocol to sector)
       +(TCCF input traffic rate + TCCF output traffic rate
       + input/out line protocol to TCCF)
       + 2 x(SYSCON input traffic rate + station output traffic
       + input/output line protocol to SYSCON)
       + 8 x(station input traffic rate + station output traffic
       + input/output line protocol to station)
       +(input NCS traffic + output NCS traffic + input/output
       line protocol inter processor)
```

interrupt structure by providing a priority schedule capability, and providing the software necessary to handle all interrupt and I/O activities.

The Executive Sequence Controller (Task Scheduler) will determine on the basis of a priority assignment which of the scheduled tasks will be given control of the central processing unit. The priority of each task will be maintained in a data base table with initial priority assignments assigned during the system software development. This technique provides capability for the priority assignments to be adjusted by simply changing the table entries. This table will remain part of the deliverable software; however once an acceptable priority assignment has been determined, capability of any operator to gain access to this table via any I/O device will be prohibited.

FIGURE 7-23. TOTAL EFFECTIVE THROUGHPUT RATE FOR NCS FRONT END PROCESSOR

The executive software must also support a file structure as required for the CPMAS data base. In addition this software will provide a data base management system which supports maintenance of the various system queues (e.g. the task queue, the measurement queue, the fault isolation queues, and the display/report queue, etc.).

7.4.2.1.3 NCS Monitor Software

CPMAS data collected by the monitor and assessment software will be manipulated via a data base management program. This serves as the interface to the CPMAS data base. This software accepts commands via telemetry, from the operator, and from application programs. The management system maintains control tables and directories to allow for efficient data base utilization. The CPMAS data base and the management system is discussed in more detail in Section 7.4.2.2.

The CPMAS NCS monitor software monitors two categories of data. They consist of discrete digital status bits and performance parameters for the network equipment. This software will be capable of supporting dynamic monitor control directories. The monitor scan directory will have two levels of control. Monitor points which indicate the status of the mission bit stream will be monitored continuously and any change will be passed on to the assessment and fault isolation functions immediately. The second set of monitor points are less critical in nature. They are used in such areas as reporting functions and monitor data resolution tests. These can be scanned at slower rates and have lower priority in the executive task schedules.

In addition, the monitor software must accept commands via operator input. The operator will be able to initiate individual monitor scans as necessary.

This software must also interface with the telemetry subsystem. The telemetry software provides the interface between the monitor program at nodal control station and the points to be monitored at the remote sites.

7.4.2.1.4 NCS Assessment Software

The monitor software provides the primary input to the assessment software subsystem. The assessment modules include the analysis, fault isolation, and corrective action funtions. The assessment programs provide the means to assess the quality of the digital transmission system by analyzing performance measurements. This software will assess the status of individual equipments and the CPMAS network as a whole.

The equipment status is assessed by means of alarm analysis algorithms. The alarms are prioritized according to severity, with the critical (high priority) alarms scheduled to be processed first. The fault isolation algorithms are then executed to determine the primary cause of the alarm. The alarm analysis algorithms will be capable of being scheduled for execution either automatically (by software) or by an operator. A detailed description of the fault detection/isolation technique is given in section 5.3.

The assessment of the network characteristics is based on analog, binary and pulse count parameters for the network equipments. The processing software will store and process these input parameters as shown in Figure 7-24. This data will be used as input to threshold and trend processing software. The threshold analysis processing includes at a minimum the comparison of performance parameters to a set of performance criteria thresholds. The determination is then made if the equipment is operational within exceptable tolerance limits. If the equipment is out of tolerance fault isolation software will be executed to locate the cause of abnormality. A detailed description of the performance assessment technique is given in section 5.1.

The threshold assessments are stored and analysed in a time ordered sequence. The ordered data is used in the trending calculations to predict possible future performance threshold failures. A set of unique processing algorithms will be executed for the performance parameters using trend values. The parameters will be extrapolated to determine if and when the performance parameter will cross marginal and abnormal thresholds. A detailed description of the trend analysis technique is given in section 5.2.

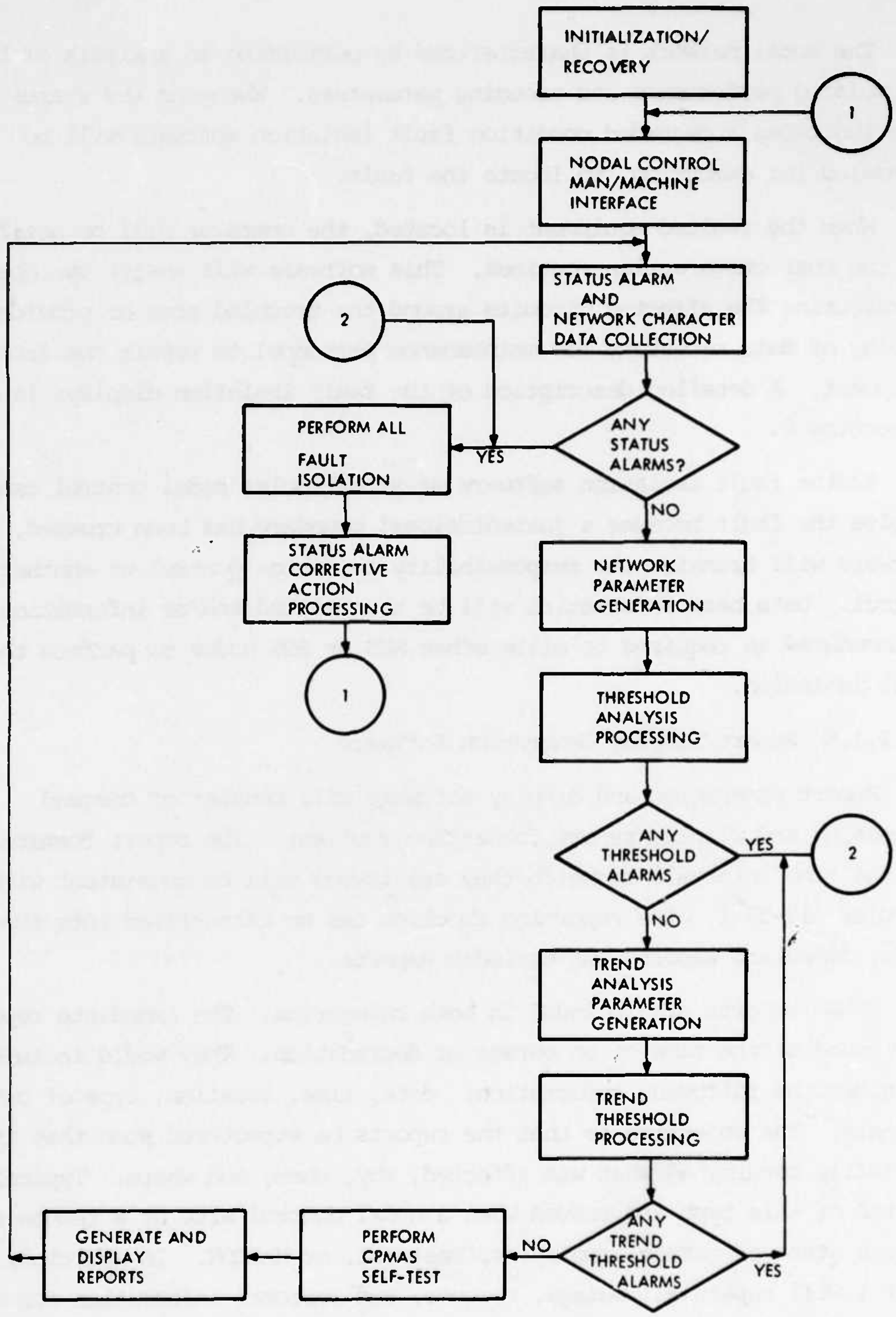

FIGURE 7-24. CPMAS-NCS SOFTWARE FLOW DIAGRAM

The total network is characterized by performing an analysis of the accumulated performance and trending parameters. Whenever the status data base indicates a degraded condition fault isolation software will be scheduled for execution, to locate the fault.

When the faulted equipment is located, the operator will be notified via the corrective action routines. This software will assist the operator in rerouting the affected circuits around the troubled area or provide a display of data necessary for maintenance personnel to repair the faulty equipment. A detailed description of the fault isolation displays is given in section 6.

If the fault isolation software at a particular nodal control cannot resolve the fault because a jurisdictional boundary has been crossed, the software will transfer the responsibility to sector control or another nodal control. Data base information will be transmitted and/or information access accommodated as required to allow other NCS or SCS nodes to perform the fault isolation.

7.4.2.1.5 Report/Display Generation Software

Report generation and display software will consist of command processing and display/report formatting routines. The report formats and the time intervals at which they are issued will be consistent with DCA circular 310-55-1. The reporting function can be categorized into two types, Immediate Reports and Periodic Reports.

CPMAS reports are included in both categories. The immediate reports are issued at the time of an outage or degradation. They would include at a minimum the following information: date, time, location, type f outage, comments. The objective is that the reports be structured such that it can be readily determined what was affected, why, when, and where. Typically reports of this type are issued when a nodal control site or a remote site is in a state of outage, isolation, restoral, or HAZCON. In addition, nodal control will report all outage, reroute, and restoral information for multi-channel facilities and special interest circuits.

Periodic reports will also be initiated. These reports are issued to the appropriate authorities at specific time intervals. They will convey

statistics of station outages, link outages, trunk outages, channel outages, circuit outages, and HAZCONS. The nodal control software system will provide computer assistance in report preparation. It will provide the capability for both machine and controller entry of address information and data items into the report formats. The software will enter, into the report formats, data items available in the monitor and assessment data base. The operator will then enter any necessary additional data not automatically inserted. The software system will allow for editing and display of completed reports. In addition, the capability to provide hard copy will be supported. Report transmission in both the manual (operator initiated) and automatic (software initiated) mode will be supported.

In addition to the processing necessary to aid in report generation, the software system will support other displays. One such group of displays will consist of high priority information. These will address critical alarms and faults, commands from higher levels (sector control), and status summaries. There will also be routine status displays. These will provide information pertaining to parameters related to alarms, monitor points, and fault isolation. In addition, the software will maintain working storage allocation parameters so that the operator can assess the status of the working storage. This status information will give an indication of the system loading.

7.4.2.1.6 Man/Machine Interface Software

Software will provide access authorization and syntactical analysis on each command/request input by an operator via the system Visual Display Unit (VDU). The software will require each VDU user (operator) to "identify" himself prior to being granted access, by the software, to system information. The software will maintain a table which relates each VDU command/request to the access levels allowed to use it. Thus an operator identified with a specific access level is prevented from inadvertently requesting and receiving information he is not entitled to. The access authorization may be graned as a result of a combination of hardware and software elements provided by the system. The technical controller, (highest access authorization), will be provided with a unique physical identification (i.e., key) and/or a logical

identification (password), which will be properly analyzed by the software before access to the total set of VDU commands/requests will be allowed.

Each command/request (including subparameter fields) entered by an operator will be syntactically analyzed by the software to insure that it is within its specified format, which will insure the information request is properly processed.

Through the Visual Display Unit (VDU), commands are entered in the following general format:

cccc ppp...ppp...		(up to 80 characters)
	cccc	- Command Designator which is a variable number of characters.
		- Space serves as separator; a comma is also acceptable.
	ppp	- Variable number of characters to represent a parameter; multiple parameters are deliniated by separators.

The ability of an operator to "talk" to the computer in a natural language (i.e., English) has long been a system design goal. If the computer is to carry out an intelligent conversation in a natural language it must be capable of unambiguously recognizing all the many syntactic and semantic variations of the language. To date this has not been done. For this reason we revert to "Artificial Languages" to allow the operator to "talk" to the computing system. The major weakness of Artificial Languages has been the awkwardness of the language. Operators were continually required to refer to the "book" to find the appropriate command/request to perform the desired function.

As a result of an analysis of the functions to be performed by the operators in the CPMAS system a typical Artificial Lanugage was designed. The Commands/Requests contained in this language are intimately related to the functions they perform.

This is not a natural language, however, after using this Artificial Language for a relatively short time the necessity for referring to the "book"

to find the appropriate command/request should be minimal. In addition to the English language commands, the language is designed for ease of implementation in software. Each Command/Request consists of four to seven (4-7) alphabetic letters, with the first two letters of each being unique. Thus the "Decoding" logic for recognizing commands/requests requires a scan on only the first two characters. The operator has the option of inputting only the first two characters of the command or the first two characters up through the last character and having the system accept and act on the command/request.

The Technical Control function includes acting as a system operator for the CPMAS computer/software system, monitoring hardware, software, and circuit quality, and instituting on-line maintenance and diagnostics on hardware and software. Table 7-3 lists a typical set of commands available to the Technical Control position.

TABLE 7-3.- Technical Control Function Commands

TEST	- execute a diagnostic program
UTILITY	- load a utility program into core memory
RUN	- execute a previously loaded utility
BEGIN	- start the CPMAS system
HALT	- stop the CPMAS system
HISTORY	- obtain and display CPMAS history data
STATS	- display CPMAS utilization statistics such as queue utilization, storage allocation parameters, real time utilization, etc.
SRVC	- initiate manual service report generation and distribution function
PRINT	- obtain a hard copy of a display, message, or report
NONPRINT	- disable the PRINT option if previously invoked
MONITOR	- display monitor data for specified equipments
TREND	- display trend data for specified parameters
LIST	- display specified data parameters and tables
CHANGE	- change specified data base elements

7.4.2.1.7 Initialization/Recovery Software

The CPMAS software system will provide for system startup including hardware I/O controllers, memory buffer initialization, timer, control flag and data base initialization. This software will also provide for automatic initialization of certain parameters relevant to the communication lines, thresholds, VDU terminal configuration and communication channel synchronization. The communication channel parameters and related information will be formatted as command messages and transferred to the appropriate Front End Processor (assuming more than one is require). Parameter initialization is based on operator inputs which will be obtained through an interactive dialogue between the system and the Nodal Control operator.

It is anticipated that program load will be accomplished via an off-line storage device (mass memory) associated with the NCS. After the program data base and required operator inputs have been loaded, the program proceeds to initialize the system automatically. In order to provide the NCS with a recovery capability, it is necessary for the operational NCS software to maintain software system status records. This data will be updated periodically in such a manner that the most recent information is always available for recovery purposes if required. For reliability purposes, a preferred technique will be to store this data on two unique off-line storage devices, as well as in memory, to insure the required data is retrievable, thus providing capability to recover from non-catastrophic failure.

The program will compute a checksum of the CPU memory containing the instructions and fixed data base values, and compare this computed checksum with a predetermined value to insure the loading has been successful. This checksum computation is in addition to any block checksum (CRC or the like) which may be performed on transfer of data from the off-line storage device into memory. The checksum defined for this use can be defined such that the location and the contents of the location are linked in the computation, thus giving confidence that not only was the correct data loaded but that it has been stored in the proper location by the system's general loader software.

NCS recovery procedures subsequent to a catastrophic NCS failure require a reload and restart as performed by the NCS operator during start up.

Recovery procedures subsequent to non-catastrophic NCS failure will require no reload (as in start up), but will require partial re-initialization and re-establishment of data base and certain parameters before re-initiating normal processing.

7.4.2.1.8 CPMAS Self-Test Software

A CPMAS system self-test module will also be included in the software package. This module will verify that CPMAS elements are functional. The self-test will be performed on a regular basis as a background routine to maintain confidence in the equipment performing the CPMAS NCS mission. These checks address the peripheral equipments required to perform the system objective. In the on-line configuration, the tests are separated into two groups based on the frequency of execution. A portion of the peripheral exerciser routines are scheduled for execution on a low priority basis, and on a time available basis. These tests are performed when there is nothing else of higher priority to be performed by the software, as long as they are executed at a minimum frequency. Only as a result of an exerciser failure or a performance anomally will a second set of on-line test routines be executed. The execution of these routines is manually requested by the Technical Control operator as a result of a suspected or confirmed system failure(s). These tests are executed once per request, with the results displayed to the operator for further manual action. The resulting actions are the operator's responsibility and generally involve the ability to reconfigure the system equipments, allowing the system to remain in the on-line mode of operation to perform the system objective. For purposes of commanlity, many of the software routines which execute in the on-line mode, will also be executed as part of the off-line repertoire of routines. The non-periodic routines are stored on the mass memory device, and loaded for execution when requested by the operator. All periodic background routines remain in core to minimize access time.

The off-line software is used to test and isolate CPMAS hardware faults. Each piece of equipment has a unique test routine or sequence of tests with the software, constructed to allow the Tech. Controller to execute the individual tests in a mutaully-exclusive manner or, for a more complete test,

allow him to select sequences of tests, to operate in concert with each other, providing a more realistic environment for testing the equipment. Operationally, the controller executes a single isolation and test routine for the failed equipment until the failure(s) is corrected, whereupon he initiates a sequence of tests to simulate a more realistic environment and insure that nothing else has been disturbed during the repair procedure. This software is constructed to link with those portions of the VDU Monitor software required to allow the Technical Controller to operate with a VDU for controlling this off-line activity.

7.4.2.1.9 CPMAS Data Base Functional Description

The CPMAS data base can be partitioned into four major segments; namely, Monitor Data, Assessment Data, Report/Display Data, and Connectivity Data.

7.4.2.1.9.1 Monitor and Assessment Data

The site Monitor and Assessment data is the heart of the CPMAS system. This data consists of the information related to each site within the nodal control area. This information content includes scan control data, monitor control data, equipment measurement data, site monitor data, alarm/threshold data and parameter history data. The scan control and monitor control data bases will be used by the operational software to specify site data input procedures. These tables will be accessible by the operator. The technical controller can modify software execution of both the monitor and scan software loops via the parameter data contained in these tables.

The equipment measurement data includes all Binary Alarm, Pulse Alarm, and Analog Data. It includes both local station information and remote site data items.

A preliminary estimate of the site and equipment monitor point data has been made. Table 7-4 gives the number of packed 16-bit words required to characterize each type of equipment. A number of assumptions were made. The radio is characterized according to the specification for the DRAMA radio, AN/FRC 163. The TSEC/KG is assumed to be a KG-81. The second level multiplexer (mux) is characterized as a TD-1193 and the first level mux is

TABLE 7-4. PRELIMINARY CPMAS DATA BASE ESTIMATE - WORDS

ALARM MONITOR DATA REQUIREMENTS (WORDS) PER CPMAS EQUIPMENT

	ALARM				
EQUIPMENT	ANALOG	BINARY	COUNT	OTHER	TOTAL (WORDS)
SVC CHANNEL	0	2	1	2	5
RADIO	14	3	1	2	20
TSEC/KG	2	1	0	2	5
FIRST LEVEL MUX	0	1	1	2	4
SECOND LEVEL MUX	0	1	2	2	5
SUB MUX	0	1	0	2	3
SITE ALARM/MONITOR	4	2	0	2	8

assumed to be a TD-1192. In addition, the maximum number of monitor data points for each piece of equipment was used.

Based on the above equipment estimates, an estimate for the CPMAS transmission system model has been derived. This model is discussed in detail in Section 2.1. Briefly, the model used for the estimate contains one nodal control station, seven terminal stations, three branching repeaters and eleven digital repeaters. Table 7-5, gives the number of each type of equipment in the model. The total equipment in the model was multiplied by the number of words per equipment to yield an estimated monitor data base of approximately 2,300 16-bit words.

The CPMAS monitor and assessment data also includes Alarm/Threshold and Parameter history data. The threshold data base includes a predetermined set of criteria thresholds to define equipment performance categories. The thresholds will be used to characterize normal, marginal, and abnormal operation. The Parameter history data consists of both calculated parameters and raw input data samples. This data is used by the trending algorithms to predict system operational characteristics.

The CPMAS monitor and assessment data will be logically structured around the site oriented nature of the system. Its organization will follow a ROUTE-SITE-EQUIPMENT hierarchy as shown in Figure 7-25. Since the primary function of this data is to provide status (not connectivity) the data base has a relatively fixed form. Basically, a "route" directory will contain a list of ports at the nodal control station. For each port there will be a pointer to a list of all sites on that route. The individual site tables will then contain pointers to the equipment tables for that site. The equipment tables in turn will contain the status information for each piece of equipment.

7.4.2.1.9.2 Display/Report Data

Display/Report formats will also be a part of the CPMAS data base. These elements of the data will provide the means whereby CPMAS information can be communicated to the operator. It will provide the means whereby the operator can communicate with the CPMAS system. Additionally, it will provide support for the required record keeping and reporting functions.

TABLE 7-5. PRELIMINARY CPMAS DATA BASE ESTIMATE - EQUIPMENT

PRELIMINARY CPMAS DATA BASE ESTIMATES (CONT.)

EQUIPMENT TYPE	QUANTITY OF EQUIPMENTS				TOTAL WORDS FOR NODAL AREA EQUIPMENT
	NODE A	TERM. STATION (7)	BRANCH REP. (3)	DIG. REP. (11)	
RADIO	8	7	9	22	920
TSEC/KG	12	7	9	0	140
FIRST LEV. MUX	48	56	0	0	416
SECOND LEV. MUX	12	7	9	0	140
SUB MUX	48	56	0	0	312
SVC CHNL	8	7	9	11	175
SITE ALARM/MON	1	7	3	11	178
					2281 TOTAL

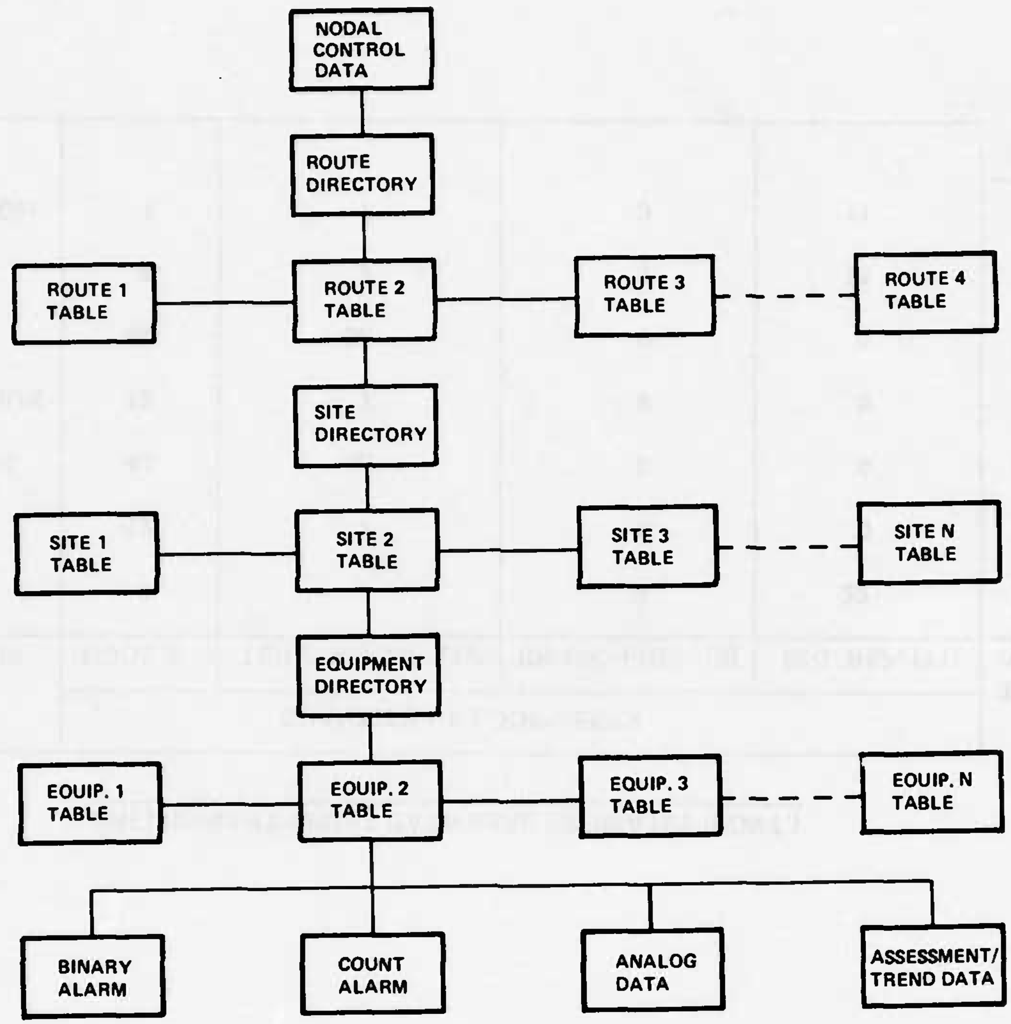

FIGURE 7-25. DATA BASE STRUCTURE FOR CPMAS DATA

More specifically, this data will support High Priority displays such as Serious Alarms and Fault Indications, High Level Requests (sector level), etc. This data will also support Routine Status Displays including node, route, site, and equipment summaries. Detailed status displays will also be maintained at the area, route, site, and equipment levels. Similarly, Fault Isolation displays on both a summary and detailed level will be provided. These displays are described in detail in Section 6.

CPMAS Queue status displays will also be maintained. These will assist the operator in CPMAS system control. Included will be Fault Isolation Queues, Processor Activity Queues, and System Logs.

Additional tutorial displays will be maintained in the data base. These support operator controlled activities. This will include the data base update activities (e.g. add/delete equipment at site, modify assessment threshold values, and changing monitor and scan points). Also included will be the corrective action displays which will present data to the operator to facilitate rapid service restoral.

7.4.2.1.9.3 Connectivity Data

Finally, there will be data elements associated with the fault isolation requirement. As previously stated, the fault isolation routines will rely primarily on the monitor and assessment data. However, additional information will also be required. The fault isolation software will by necessity have to resolve site, route, and equipment ambiguities. To do this, site and equipment interconnection information is required. Basically, for each nodal control station it is necessary to know all the links which terminate at the station and all sites within its area of responsibility. In turn each link must be logically connected with the two stations it directly interfaces, and the routes (trunks) that lie on the link. At the next lower connectivity level, each route must be logically connected to the groups (super groups) and trunks it includes. Similarly channel data must be logically connected to each of the higher hierarchical elements of which it is part (route, trunk, group). Finally, each sub-channel must point, at a minimum, to its associated channel. Simply stated it is necessary to be able to enter the connection hierarchy at any level and proceed up or down the structure as necessary to resolve ambiguities.

7.4.2.1.10 CPMAS NCS Program Language Considerations

The purpose of this section is to consider the question, what language or combination of languages could be used to implement the CPMAS NCS software.

There are two levels of language from which to choose; machine-oriented languages (MOL) and higher-level languages (HOL). The selection of a HOL will depend on the ability of the language to simply and efficiently implement the CPMAS software. The choice of a HOL vs a MOL is not mutually exclusive. We can use a HOL in conjunction with a MOL to implement the system.

In most areas of application, the question of choice between HOL and MOL is not considered to be open. The desirability of higher level language implementation is overwhelming. Here the advantages with special reference to CPMAS will be examined.

7.4.2.1.10.1 Higher Order Language Considerations

The HOL has the advantage of universality. It is common to many computers, many persons, and many installations. This commonality makes the system using it tolerant to changes in personnel, equipment, and software.

This is especially important in the CPMAS system since it will exist in an environment of constant update.

A HOL is easy to use. This, by definition, has been designed into the HOL's. Programs are easier to implement in Higher-level languages. As a result, the reduction in software production (implementation) time can be significant. Program source code is easier to read and understand in a HOL. This simplifies debugging and program maintenance. One programmer can read another's programs; and he can more readily reread his own programs after a substantial time lapse.

It may be claimed that HOL's are self-documenting, since the computer generates program listings in a highly readable form. The need for comments is indeed much greater with machine-oriented (Assembler) language than with higher-level language, but that this need still exists is exemplified in that the specifications provide for comments in all the better-known HOL languages:

COBOL, FORTRAN, JOVIAL, etc. Further, the requirement for flow charts is not reduced.

Higher-level languages provide limited automatic program debugging and error prevention. There are two aspects of this. First, the use of a HOL itself eliminates whole categories of programmer errors. Attention is focused on algorithms and the design, rather than detailed machine language bugs and tricks. By the same token, it introduces new sources of errors (i.e., more rigid structure); however, there is no doubt that the gain here is significant. Second, program diagnostics are a part of every compiler. As such, their quality and quantity is not so much dependent on the language as on the system configuration and design of the particular implementation.

Program debugging begins in the initial stages of program compilation. Most of the mechanical errors, like keypunch errors, will be detected by the compiler diagnostics. One way to capitalize on this is to compile the program on a computer other than the object computer. Most of the "mechanical" debugging can be accomplished without using the object computer. This is advantageous in a circumstance where fast turnarounds are available on another computer, or where availability of the object computer for program debugging is severely constrained, as is frequently the case in a developing system.

The classic objection to the use of a HOL is the non-optimization of resultant object code. The compiler cannot optimize as tightly as a programmer. Of course, this is somewhat dependent on the programmer. An experienced programmer can avoid some of the waste that is a consequence of the blind use of a HOL. One cannot, however, avoid the extra housekeeping that is necessitated by the generality that is designed into the compilation process. The more generality a language provides, the more functions it can perform, the less likely it will generate efficient object code. The economy, or lack of it, is measured in memory utilization and in running time of the object code programs. It's obvious that the efficiency, or lack thereof, of a particular HOL is intimately dependent on the particular compiler version, machine configuration used, and functions it is used to implement.

A second objection to the use of a HOL is the lack of "real-time" features. This is mainly evident in the area of Input/Output and Interrupt Handling. In the CPMAS system, although each site will report its status on exception (i.e., when a change occurs) the nodal control processor must be capable of handling (Inputting/Outputting) large quantities of data at relatively high rates of speed. To accomplish this, assembly language modules may be necessary to optimize the equipment interface programming.

7.4.2.1.10.2 CPMAS Higher Order Language Requirements

A brief survey of possible candidate higher level languages has been done. The languages presented are rated relative to presently identified CPMAS software requirements. The language capabilities compared are stated below.

a. Bit Manipulation - This is the facility to set/reset/sense specified bits within a computer word. This language capability is required for the CPMAS software to manipulate status indications, alarm words, and various system software sense flags.

b. String Manipulation - This is the ability to move or modify individual characters or character strings easily. The CPMAS software system will utilize this capability extensively in the display/message generation subsystem. In addition, efficient string manipulation is required in the telemetry interface since remote site data will be transmitted as blocks of characters.

c. Logical Operations - This is a measure of the decision-making capability of the language. The CPMAS software requires this characteristic extensively. Alarm and threshold analysis is basically a group of interrelated logical operations. Similarly, performance assessment and fault isolation programs are very dependent on the logical characteristics of the selected language.

d. Floating Point Arithmetic - The capability of the selected language to perform arithmetic calculations simply, efficiently, and accurately is an important CPMAS software consideration. Parameter calculation is an integral part of the performance assessment and trending software functions.

e. Real-Time Input/Output - This characteristic is vital to the CPMAS software system. It is required in the area of telemetry interface and equipment interface. A flexible and efficient software architecture is necessary to accept, manipulate, and disseminate CPMAS data. At the "same" time the operator must be allowed access to the system, in order to maintain manual control of the system. The selected language must be adaptable to a prioritorized multi-task and interrupt architecture.

f. Real-Time Clock Access - It is required that the CPMAS software system has access to a real-time clock. The clock is used in time dependent software functions. These exist in both the assessment and trending software. In addition, the time of fault occurrance is a necessary input to the fault isolation routines.

A summary of the program languages considered and typical mini-computer systems which support them is given in Table 7-5. It should be noted that each language (except COROL) is also available for large systems (IBM 370). This would allow for off-line compilation and preliminary debug. It is also important to note that none of the languages adequately support the "Real-Time" requirements of the CPMAS software.

The language comparisons are presented in Table 7-6. The most common higher languages in the mini-computer field are FORTRAN, COBOL, and BASIC. One or more of these three languages is supported by the majority of the major mini-computer manufacturers. Each of the languages, however, has a specific weakness in the CPMAS application. FORTRAN is very strong in the computational aspects of the system, but is less suitable for data string and bit manipulation. COBOL, on the other hand, is very good for data manipulation, but is not well suited for the computational and system control aspects of the problem. Lastly, BASIC is inappropriate since it is generally an "interperative" rather than a "compiler" language and is therefore far too slow and inefficient to be considered for the CPMAS requirement.

JOVIAL may overcome some of the above weaknesses; however, it presently is supported on a limited number of mini-processors. ALGOL, on the other

TABLE 7-6. PROGRAMMING LANGURAGE TRADE-OFFS

PROGRAMMING LANGUAGE CHARACTERISTICS

	DIRECT BIT MANIPULATION	DIRECT STRING MANIPULATION	LOGICAL OPERATIONS	FLOATING ARITH.	MINI-PROCESSOR LANGUAGE AVAILABLE	REAL-TIME CLOCK	REAL-TIME INPUT/OUTPUT
FORTRAN	POOR	POOR	GOOD	YES	MOST MINI-PROCESSORS	NO	NO
COBOL	POOR	GOOD	POOR	NO	HP3000CX, PDP 11/70	NO	NO
ALGOL	POOR	GOOD	GOOD	YES	DATA GEN. NOVA, PDP-8, HP2100	NO	NO
COROL	GOOD	GOOD	GOOD	YES	PDP-11/45, 11/70	NO	NO
JOVIAL	POOR	GOOD	GOOD	YES	IBM 4π, DELCO M362F	NO	NO

NOTE: REAL-TIME CLOCK AND INPUT/OUTPUT PROCESSING MUST BE DONE IN ASSEMBLY LEVEL LANGUAGE.

hand, is available on a slightly broader field of "standard" mini-computers. However, ALGOL, like the other languages, is not suitable for the real-time problem as seen in Table 7-7.

Finally, CORAL (Class Oriented Ring Associative Language) is the most applicable of the languages compared from a CPMAS software requirements viewpoint. The language provides the major features of ALGOL and JOVIAL and in addition, has strong bit manipulation features. It has two drawbacks. Like the other languages considered here, it lacks efficient real-time capability and in addition, it is in very limited use in this country. It was developed as a communication language in England and has been used with success there, but as yet has seen limited use here.

In summary, it is apparent that no one of the languages considered here can solve the CPMAS software functions in its entirety. A possible solution may be to use a suitable higher-level language for CPMAS in areas where timing is non-critical. Time critical areas could be written in machine oriented language. In addition, an assessment should be made of core storage requirements due to compiler inefficiency, and some areas if necessary may be optimized in machine oriented language. The availability of an efficient compiler should be a serious consideration in computer selection.

7.4.2.2 CPMAS-D Software Functional Requirements

The high level CPMAS-D software requirements consist of the capability to:

a. Monitor Equipment Status
b. Detect status change and perform exception processing
c. Format CPMAS-D data for transmission
d. Input/output protocol processors
e. Perform receive traffic processing
f. Perform CPMAS-D equipment self test

The equipment monitor function consists of the processing required to monitor and store the status of the individual station equipments. The status data consists of alarms, analog parameters, count values and performance assessment values. The status change detection function consists of the

TABLE 7-7. PROGRAMMING LANGUAGE CHARACTERISITICS

PROGRAMMING LANGUAGE TRADEOFFS

LANGUAGE	ADVANTAGES	DISADVANTAGES
FORTRAN	• GOOD MATHEMATICAL CAPABILITY • AVAILABLE ON MANY PROCESSORS • RELATIVELY EFFICIENT	• POOR BIT/STRING MANIPULATION (REPORT GEN.)
COBOL	• GOOD FOR REPORT GEN.	• LIMITED PROCESSOR AVAILABILITY • POOR MATHEMATICAL FUNCTION • POOR LOGICAL FUNCTIONS • VERY VERBOSE • RELATIVELY INEFFICIENT
ALGOL	• FLEXIBLE • GOOD FOR ALGORITHMIC FACILITY • STRUCTURED	• LIMITED PROCESSOR AVAILABILITY
COROL	• FLEXIBLE • ALGOL LIKE STRUCTURE • RELATIVELY EFFICIENT	• LIMITED PROCESSOR AVAILABILITY • LIMITED USE
JOVIAL	• FLEXIBLE • GOOD REPORT/DISPLAY GEN. FACILITY • STRUCTURED	• LIMITED PROCESSOR AVAILABILITY

processing required to determine alarm, out-of-tolerance and status change conditions. This provides the basis for the CPMAS-D exception processing which, in turn, determines the status data to be transmitted to the station control and/or the nodal control positions.

The traffic preparation function consists of the processing required to format the CPMAS-D monitored status (derived) data into system communication channel traffic formats.

The receive traffic function consists of the processing necessary to analyze the received traffic and perform effectivity processing.

The CPMAS-D equipment self test is that processing necessary to test and evaluate the CPMAS-D system.

7.4.2.2.1 CPMAS-D Functional Interface

The CPMAS-D functional interface, as derived from the above requirements, is illustrated in Figure 7-26. The input data consists of the following:

a. Binary Alarm Data
b. Analog Parameter Data
c. Count Parameter Data
d. Performance Data
e. Received message types
   - data request
   - monitor point/threshold control
   - redundant equipment switchover control

The binary alarm data consists of groups of individual binary alarms as monitored by the CPMAS-D equipment.

The Analog parameter data consists of the analog measurements of the equipment characteristics. This data is subject to threshold analysis.

The Count parameter data consists of counted events monitored by CPMAS-D. This data is usually characterized by "m out of n" counts, and is subject to threshold analysis.

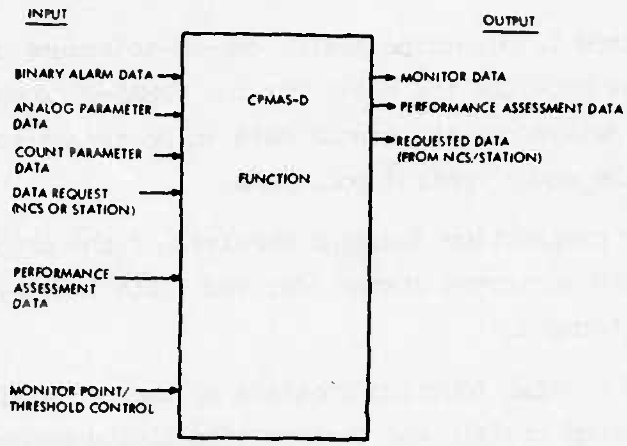

FIGURE 7-26. CPMAS-D FUNCTIONAL INTERFACE

Performance data is that data used by the CPMAS-D system as input to the performance assessment algorithms.

Finally, the message types accepted by CPMAS-D are of three varieties, the most common of which is the data request. This command can originate at either the nodal control position or the station control position. In either case, they are requests for data stored in the CPMAS-D data base. The second type of command is the monitor point/threshold control command. This request originates from the nodal control station. It is used to control the selection of monitor and assessment points and to modify threshold values. Finally, the switchover commands are used to switch in redundant equipment. This is part of the "man in the loop" procedure to activate standby equipment.

The output interface, as shown in Figure 7-26 consists of the following three data types:

a. Monitor Data

b. Performance Assessment Data

c. Requested Data

The monitor data is that monitored status transmitted from the CPMAS-D to the station and the NCS on exception. It includes Binary status changes, Analog, and count values which have exceeded predefined thresholds.

The performance assessment data is that data gathered by CPMAS-D to be sent to the NCS for further refinement and analysis.

The requested data is that data requested by the NCS or the station controller in addition to the normal exception data. This includes binary alarm values, analog values, count values, performance assessment parameters and any other equipment status information maintained in the CPMAS-D data base. Requests are made on the basis of equipment type.

7.4.2.2.2 CPMAS-D Software Functional Description

The highest level software requirements as described above are functionally allocated as shown in the CPMAS-D software family tree (see Figure 7-27). Not shown in the family tree is the off-line development, test and evaluation support software. These include the assembler/compiler, loaders, debug programs and other off-line computer software. The sections to follow describe each major software function in the CPMAS-D.

7.4.2.2.3 CPMAS-D Scan Control

This software will provide the control at the CPMAS-D to input and process the various monitored data parameters. These parameters include Binary Alarms, Analog Parameter data, Count Parameter data and performance assessment parameters. The detailed software requirements are dependent on the data collection implementation technique.

One possible technique would involve utilizing a unique interrupt for each monitored alarm. In this technique, each detected alarm or threshold crossing would activate an individual interrupt. The software would then respond to the interrupt via its interrupt handling software. Each interrupt would be serviced, and the appropriate analysis processing would be initiated. This technique will provide the maximum possible speed for recognition and

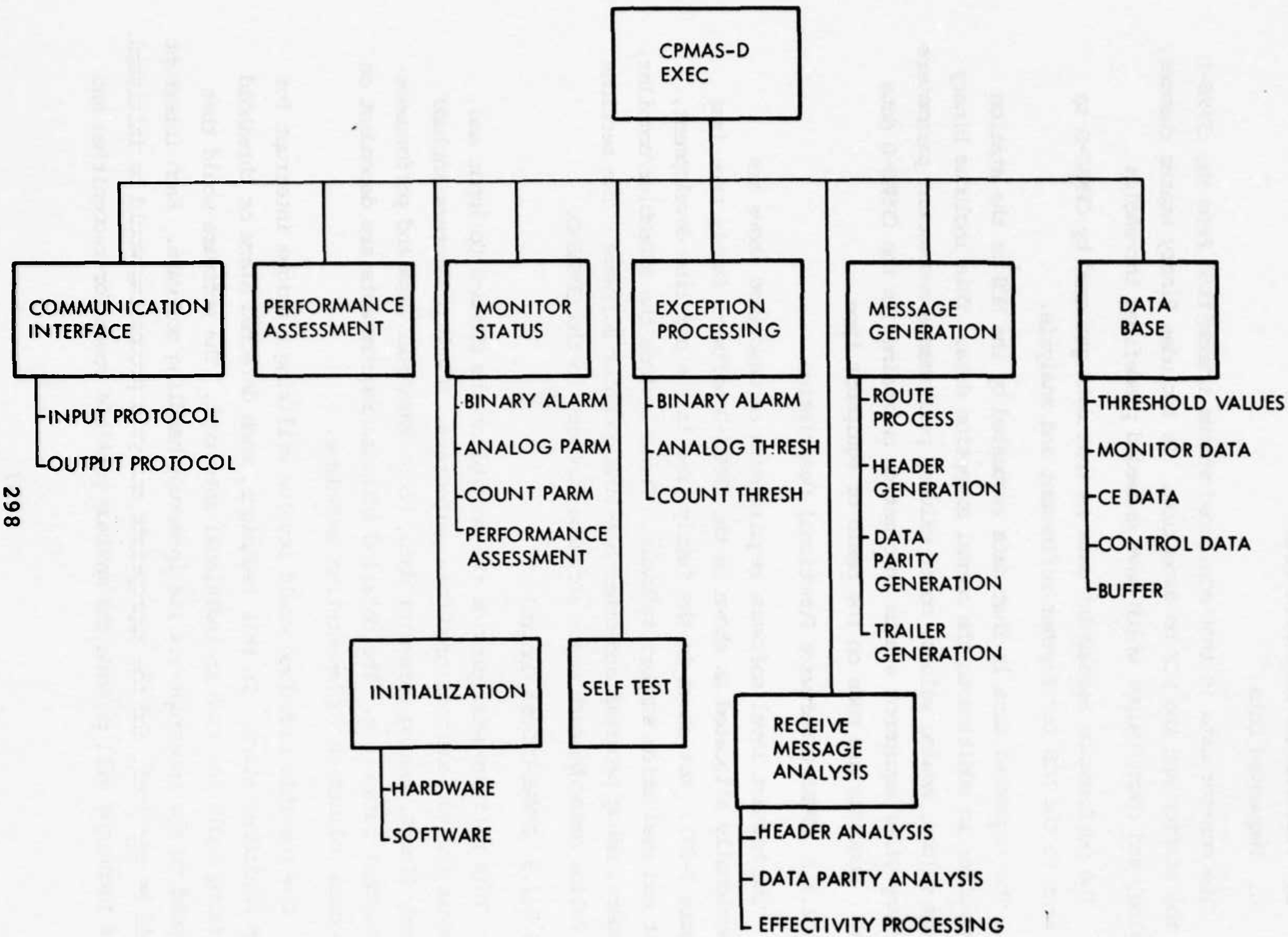

FIGURE 7-27. CPMAS-D SOFTWARE TREE

servicing of individual alarms with a low incidence of occurrence. It does, however, lead to a more complex and costly hardware/software implementation.

A second possible technique for scan control requires the hardware to provide a single interrupt for any alarm or threshold crossing. This technique requires that the software respond to the interrupt and then determine the unique alarm or threshold which caused it. This alternative increases the individual response time for each alarm relative to technique 1 described above. However, it may lower the hardware cost and complexity.

A third possible technique for scan control requires that the software address each scan point (or group of points) by a unique address. This would utilize a round-robin technique, in that each point (or group of points) would be addressed in sequence. The hardware required to implement this method could be accomplished using a number of common techniques. This scan implementation technique will, in general, require less complex hardware and software. Using this method, however, alarms will be recognized only after they have been sensed in the scan cycle. A functional flow chart of this approach is given in Figure 7-28. Since this approach appears least expensive (in preliminary study) but most time consuming in alarm reporting, it has been subjected to a timing sensitivity analysis. It has been determined, as a result of this analysis, that the processing time required is acceptable. Depending on the CPMAS station size at which the CPMAS-D exists, the scan time varies from 12 millisec to 58 millisec (see Section 7.4.2.5.4).

This appears to provide ample time for reporting the monitored status change(s) to the Nodal Control Subsystem within the system requirement time of thirty (30) seconds.

7.4.2.2.4 Monitor Status Control

This software is required to determine whether change-of-state conditions in binary (single bit) alarms and indicators have occurred. This software will also compare analog and count data with predefined threshold values to determine out-of-tolerance conditions for these parameters. In either case, when a change-of-state or threshold excedance condition exists, the software will queue for transmit that data block which contains the bits or values of interest (i.e., transmit on exception).

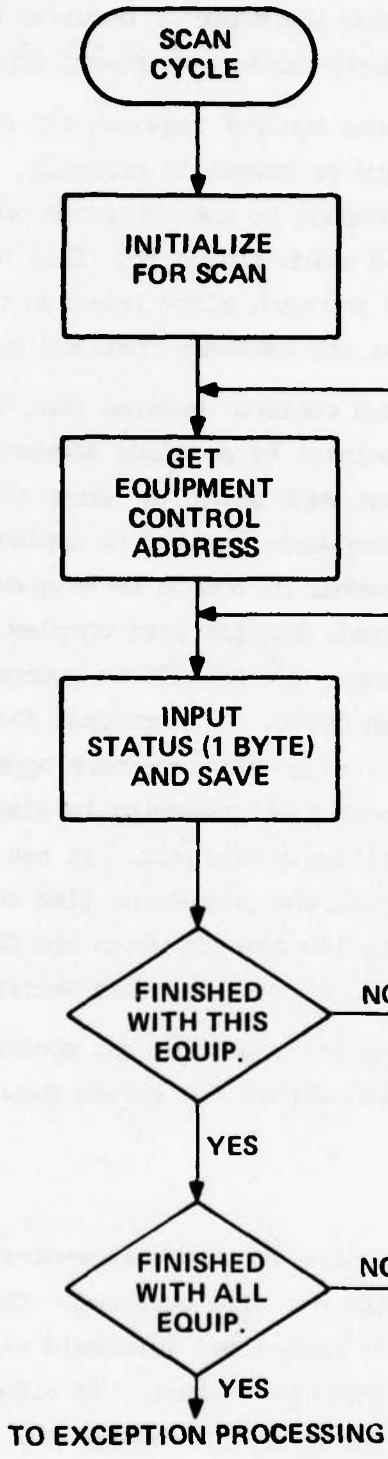

FIGURE 7-28. FUNCTIONAL FLOW OF CPMAS-D SCAN CYCLE

The detailed software requirements are again dependent on the monitor control implementation technique chosen.

One approach to monitor status control is to have a table of monitor points resident in the CPMAS-D memory which define the status points and parameters to be monitored. This method requires the software to scan this table to determine which points should be analyzed. Alternately, all points could be scanned and exception processed before the software scans the "interest" table to determine which blocks should be queued for transmission.

An alternative approach would be to substitute a "mask" for the table of monitor points. In this case, all the points of status data would be collected via the scan loop. These points will be assembled into a complete site status data base. A complete data base is always necessary, since all data must be available for request even if it is not changed status data. This data base will be segmented (formatted) into transmission blocks as specified by the selected line protocol. The exception processing function will flag each stored data block, indicating whether a status change has been detected (or not detected). The software will then scan each data block and compare those with status changes indicated to a "mask of interest". Those data blocks not "masked out" (i.e., suppressed for transmission) will be placed in the transmit queue. A functional representation of this processing is given in Figure 7-29. These identified approaches, as well as other potential possibilities, will undergo further hardware/software/system trade-off analysis in order that the final detailed software requirements can be formulated.

7.4.2.2.5 Exception Processing

The software requirements for the exception processing itself are also sensitive to the hardware approach. For instance, the binary alarms could be handled in the following ways. First, the hardware could be configured such that any time a bit is "high", it indicates an alarm state. From a software point of view, this is the simplest approach. The software would only be required to scan the CPMAS-D binary data for "high" states, and when they are found it would queue the data block which contains them for output to the Station Control and the Nodal Control positions.

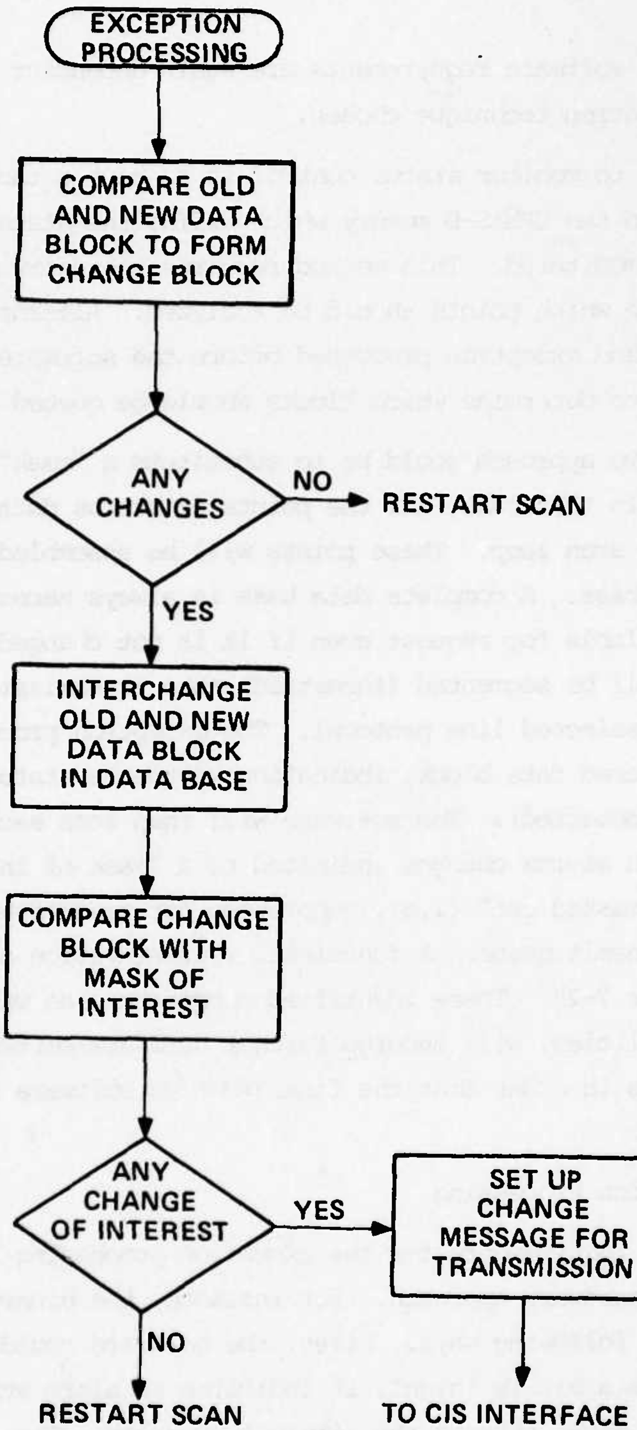

FIGURE 7-29. FUNCTIONAL FLOW OF CPMAS-D EXCEPTION PROCESSING

An obvious second approach would be to have some alarms "high" and others "low". In this case, the software would be required to perform processing to determine true alarm conditions. This method, of course, is more complex, requires more storage at the CPMAS-D, and is therefore less desirable.

A third approach which is a more general technique, requires the CPMAS-D software to report all binary alarm "changes". This approach will not require the CPMAS-D to recognize "alarm" states at all. It will only require that the software recognize state changes. The software will be required to queue for transmission those data blocks which contain changed binary alarm bits. Actual alarm processing will then be performed by the Nodal Control and Station Control positions. This method is, of course, a far more satisfactory method than the previous two, since it automatically detects both "alarm" states and "alarm reset" states. Based on the highest level CPMAS-D requirements, a combination of the first approach and the last approach may be a resonable basis to formulate detailed software requirements.

Analog/Count values can be treated in a number of ways in the exception process. One method would be to have an analog threshold table which contains a unique set of analog values for each piece of equipment at the site. This method allows maximum flexibility in system operation. It provides for each unique device having its own threshold set. This is consistent with individual "setup and tune" capabilities for each unit. For instance, although all equipments of a particular type operate within a given specification, it may be desirable to allow for individual adjustment (tolerance thresholds).

A second approach, although not as flexible, will require less storage at the CPMAS-D. Using this technique, thresholds will be stored on a per equipment "type" basis. That is, each "type" of equipment will have a single set of threshold values. This technique will decrease the implemented software to a slight extent; however, the decrease in operational flexibility may make it undesirable.

It must be stressed that the exception processing in its most basic sense requires that changes in binary data or threshold violations must be detected, identified and forwarded to the Station Control and Nodal controller systems.

7.4.2.2.6 Message Generation

The CPMAS-D outputs a single type of message. Only data messages can be created by the CPMAS-D. Further, it is assumed that the data messages are in a packed binary block format and are of fixed size. The block format is assumed to be as described in Section 7.4.2.3.8. The messages are generated either when queued by exception processing or when initiated by external (from NCS or Station Control) data requests. In either case, the CPMAS-D data block which contains the information of interest is processed for transmission. A header with the appropriate routing information is added, and a block parity is generated. Finally, appropriate framing (or trailer) characters are added. In addition, error correction coding is added if the transmission protocol requires it.

7.4.2.2.7 Receive Message Analysis

The CPMAS-D software is required to receive and analyze three message types.

a) Data Request
b) Monitor Point/Threshold Control
c) Redundant Equipment Switch-Over

All of the above message types can be generated as a result of normal Nodal Control processing. In addition, the Station Control can also produce such messages in its stand-alone or special (control responsibility passed down from NCS) modes of operation.

In all of the transmission input processing, it is assumed that the data is block formatted, as described in Section 7.4.2.3. As a *minimum*, a header analysis and data block parity analysis will be performed. In addition, this software must interface with the communication interface software to accept traffic data. The line protocol for the CPMAS-D communication channel is the same as that assumed in Section 7.4.2.3.8. In general, an asynchronous communication interface is assumed. The traffic data is collected in a serial manner, one character at a time. The characters are collected at the CPMAS-D until a full data block is formulated. Transmission blocks need not be of fixed length, although a minimum and a maximum size must be determined in order to calculate system buffer requirements. When the full block has

been assembled at the CPMAS-D, it is further processed by the message analysis software. Following header and block parity checks (and error corrections if used), the message data is parsed to determine the command to be executed. The appropriate CPMAS-D activity is then queued for processing, and the message analysis is complete.

7.4.2.2.8 Data Base

The CPMAS-D Data base consists of six basic types of information:

a) Site Status (Monitored) Data
b) Threshold Values (Predetermined)
c) Performance Assessment Data
d) Status Monitor Control Data
e) Self Test Data
f) Input/Output Support Data

The Site Status Data, as the name implies, is that data which characterizes the site equipment. CPMAS-D will have a complete record of each equipment status at the station. This data base could be configured by equipment. That is, all equipment status for a given equipment type could be grouped together. The size of this data base for a DRAMA radio system is:

Size = (No. of Bytes per Radio) (No. of Radios) + (Bytes per 1st Mux)
(No. of Mux's) + (Bytes per 2nd Mux) (No. of Mux's)
+ (Bytes per Sub Mux) (No. of Mux's)
+ (No. of Bytes per KG-81) (No. of KG-81's) + (Bytes per SVC Mux) (No. of Mux's)
+ (No. of Bytes for Site Alarm)

For a typical 2-radio DRAMA system as defined in the CPMAS Model, this data base would be approximately 140 Bytes.

A second data base element is the Threshold Value Data Base. This consists of predetermined threshold parameters. Typically, there would be four threshold levels per analog equipment parameter. They are RED HIGH, AMBER HIGH, AMBER LOW, RED LOW. The color indicates the severity of the out-of-tolerance condition. Therefore, this data base will typically have four values for each analog parameter for each unique piece of equipment. The

size of this data base is

Size = 4 x (# Analog Values per equip.) x (# of equip's).

It must be noted that this is a maximum and does not necessarily indicate the size the data base must be. It could be smaller if particular analog thresholds could be characterized by a single threshold value. For a typical 2-radio DRAMA system, this data base would be approximately 360 Bytes.

The performance assessment data is characterized as that data necessary to perform the assessment algorithms. It is basically treated like all other analog data. A system trade off will be made to determine which assessment technique will be used. Depending on the result of that study, the assessment data base will be defined and estimated.

The status monitor control data is that data required to effectively control and coordinate the equipment status information. This data base will define each binary point, analog value, count value and performance assessment parameter subject to exception processing. It should be noted that the scan control itself will be unaffected, and that the CPMAS-D status data base would be maintained in its entirety. That is to say, only points as defined in the control data base would be automatically forwarded to the Nodal Control and Station Control positions. All status data, either subject to exception processing or not, would still be available on request to both the Nodal Control and Station Control positions.

The self test data base will include all data necessary to facilitate CPMAS equipment self test and support CPMAS equipment diagnostics and fault isolation. This would include both fully automatic and man-in-the-loop procedures.

The Input/Output support data base will include data to facilitate the CPMAS-D to telemetry system interface. This would encompass channel status data, protocol buffers and interface control data.

The highest level software requirements are functionally allocated as shown in the Station Control software family tree(Figure 7-30). Not shown in the family tree is the off-line development, test and evaluation software.

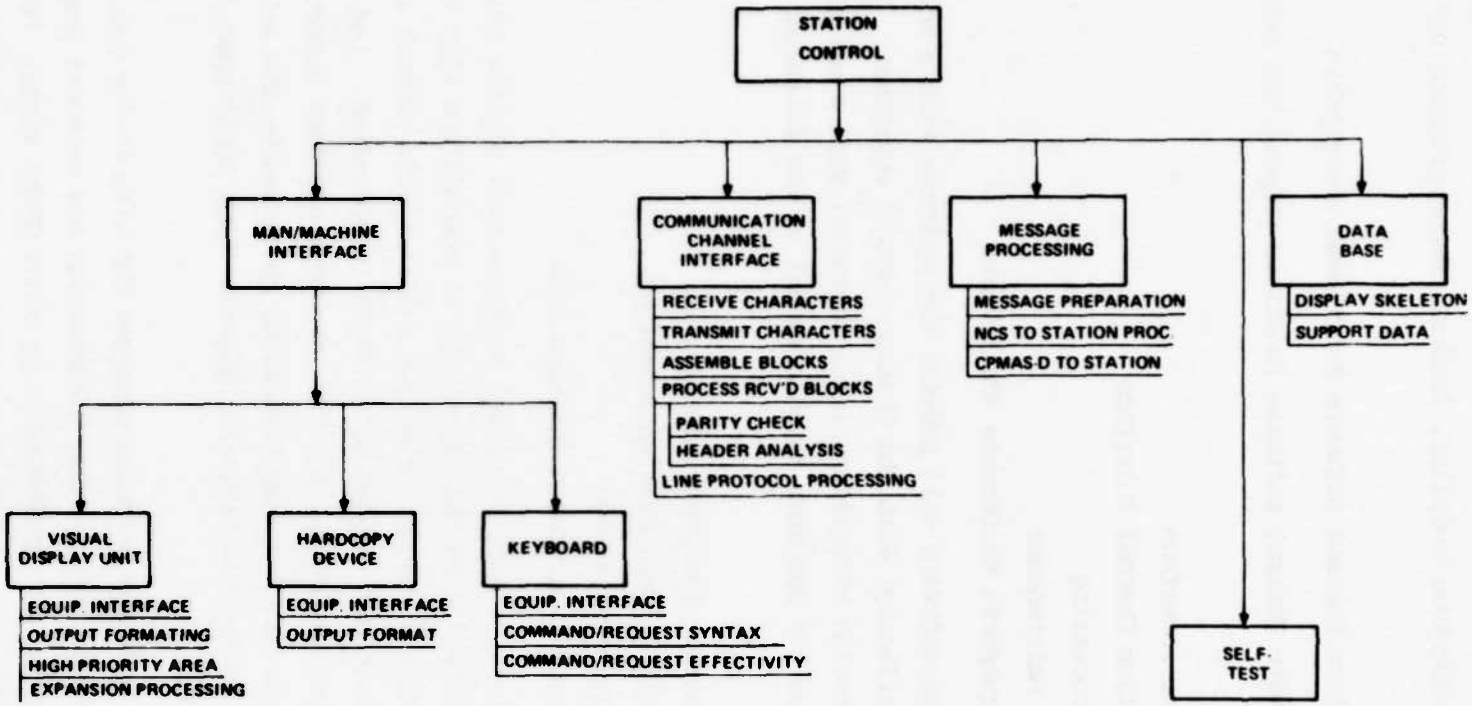

FIGURE 7-30. TASK (FUNCTION) CONTROL

These include the assembler/compiler, loaders, debug programs and other off-line software.

7.4.2.3 CPMAS Station Control Software Functional Description

The CPMAS Station Control software functions support the following five major areas:

a) Man/Machine Interface
b) Communication Channel Interface
c) Message Processing
d) Data Base Maintenance
e) Station Equipment Mantenance (Self Test)

The Man-Machine software will provide the operator with a means of communicating (interfacing) with the Station Control equipment. The software will provide the station controller (i.e., operator) with a set of commands/requests which allow the operator to gain access to the following types of information:

a) Station Control Equipment Status
b) Station Control Data Base Information
c) CPMAS-D Equipment Status
d) Nodal Control Subsystem Maintained Data

The communication channel interface software will provide the CPMAS Station Control Position with the capability to communicate with the CPMAS CIS. This communication channel interface software will support asynchronous/synchronous communications, depending on which is specified. The software will control the Station Control Position hardware elements selected for this function, perform the data transfer formatting specified by the selected line protocol, and provide for the Automatic Request (ARQ) logic specified by the selected line protocol.

The message processing software performs the effectivity processing on messages received at the Station Control Position and messages prepared by the Station Tech Controller for transmission to other CPMAS sites. Messages received at the Station Control Position are transmitted from the Nodal Control Subsystem (NCS) or the CPMAS-D. This software will process the received data

appropriately as a function of the transmitting station. The message preparation function allows the operator to enter messages in free format and perform the editing and formatting required to prepare the messages for input to the communication interface software function.

The Station Control Position software will provide equipment self test routines to check the Station Control Position hardware elements to insure the elements are operating within specified allowable limits. This software will enable the Station Tech Controller to effectively know the status of all communication channels and equipments under his control. Any Station Control Position equipment problems which are detected are immediately recognized by the CPU and the appropriate notification and report generation processing initiated. When a piece of equipment becomes suspect as a potential trouble source, the operator will be notified by display in the high priority (protected) area of the VDU. Depending on the nature of the error reported, the operator will take action to have the suspect equipment manually repaired and/or replaced.

The Station Control Position software will maintain static and dynamic data base for information reference use by the operational software in performing the Station Control Position functions. In general, the data base will maintain information which:

a) characterizes transmission and CPMAS equipments at station
b) reflects CPMAS-D reported faults
c) reflects status of the communication channel
d) reflects status of CPU peripheral equipments (i.e., VDU, Keyboard Printer)
e) reflects status of the processing functions being performed by the CPU
f) reflects status of the Station Control Position Equipment (Self Test)
g) provides fixed display skeletons for each piece of equipment.

7.4.2.3.1 Station Control Position Man/Machine Software

The Man/Machine software will be responsible for supporting the Man/Machine peripheral devices presently identified for use at hte CPMAS Station Control Position. The presently identified devices include a Visual Display

Unit (VDU), Keyboard and a hardcopy device. The required software will consist of input/output drivers (i.e., I/O equipment specific interface software) for each device, appropriate formatting of the data to/from device, syntactical analysis of input data, authorization (i.e., access) analysis of commands/requests, and effectivity processing of command/request inputs.

7.4.2.3.2 VDU Functions

The VDU and its associated keyboard is used to assist the Station Tech Controller(s) in the performance of the six (6) human controlled CPMAS Station Control functions:

a) Message Preparation
b) Status Display Request
c) Command Equipment Switchover
d) Initiate Special Tests
e) Request Hardcopy
f) Respond to System Notifications

The VDU will also be used by the system to display high priority system notification. These notifications are presented to the operator in a *protected (high priority)* area of the display screen. This area of the screen is protected in the sense that the operator will be prohibited from entering or requesting data which will occupy this area of the display.

An example of this use of the high priority area is shown in Figure 7-31. The top line has been reserved for use by the system, and the notification states that a message has been received at the site which requires the operator's attention, thus the notification in line one "MSG PENDING". In response to this notification, the operator would be required to input an acknowledge message allowing the system to erase the present screen and display the new information.

Also included on line one at the right hand side of the display is the data time group. Just below it, on line 2, is the real time in Julian time. Line 2 also contains the designation of the display type, which for this case is the RADIO at station ABC on link M0298.

CHARACTER NUMBER

```
LINE    :00000000011111111112222222222333333333344444444445555555555666666666677777777778:
NUMBER  :12345678901234567890123456789012345678901234567890123456789012345678901234567890:
--------+--------------------------------------------------------------------------------+
      1 :MSG PENDING/                                                    17/1034 FEB 77  :
      2 :                          RADIO-ABC M0298                       48/1034         :
      3 :PARM      STAT PARM          STAT PARM     STAT PARM     ALM VALUE PARM  ALM VALUE :
      4 :                                                                                :
      5 :AXMT           ABER               APWR          AXMTAFC            ABER         :
      6 :BXMT           BBER               BPWR          BXMTAFC            BBER         :
      7 :ARCV           ASCBSOUT           ASTAT1        AXMTPWR            APWR         :
      8 :BRCV           BSCBSOUT           BSTAT1        BXMTPWR            BPWR         :
      9 :ATIM1          ASCBSTIMEN         ASTAT2        AFINVLT            AFRM         :
     10 :BTIM1          BSCBSTIMEN         BSTAT2        BFINVLT            BFRM         :
     11 :AMBS1OUT       AFRMSYN                          AFINCUR                         :
     12 :BMBS1OUT       BFRMSYN                          BFINCUR                         :
     13 :AMBS2OUT       ASCBSTIMOUT                      ARCVVLT                         :
     14 :BMBS2OUT       BSCBSTIMOUT                      BRCVVLT                         :
     15 :ASCBSIN        AMBS1OUT                         AAGCVLT                         :
     16 :BSCBSIN        BMBS1OUT                         BAGCVLT                         :
     17 :ADEMOUT        AMBS2OUT                         ARSLVLT                         :
     18 :BDEMOUT        BMBS2OUT                         BRSLVLT                         :
     19 :AMODOUT        AMBS1TIMOUT                      ARCVMIX1                        :
     20 :BMODOUT        BMBS1TIMOUT                      BRCVMIX1                        :
     21 :AXMTFRQ        AMBS2TIMOUT                      ARCVMIX2                        :
     22 :BXMTFRQ        BMBS2TIMOUT                      BRCVMIX2                        :
     23 :AXMITPWR        ARCVRAFC                         ARCVLO2                        :
     24 :AXMITPWR        BRCVRAFC                         BRCVLO2                        :
        +--------------------------------------------------------------------------------+
```

FIGURE 7-31. STATION CONTROL RADIO STATUS DISPLAY

Line 3 provides the labels for the data column entries. The data is grouped in either PARM-STAT (Parameter-Status) sets or PARM-ALM-VALUE (Parameter-Alarm-Value) sets. Binary data is represented by the parameter designator followed by its status indication. Under the PARM heading is the particular parameter identifier, and under the STAT heading is the status of the respective parameter. "ALM" will appear under the STAT heading for alarmed parameters. The space will remain blank for unalarmed parameters.

Analog and count parameters are represented by the parameter designator followed by its alarm state and the parameter value. The alarm states will typically be RH (red high), RL (red low), AH (amber high), AL (amber low), depending on the alarm severity. If the parameter is unalarmed, the space will remain blank. In either case, the paramter value will be displayed in the value column for the particular parameter.

7.4.2.3.3 Man/Machine Interface - Visual Display Unit

The Visual Display Unit (VDU) is the primary physical interface between the Station TEch Controller and the CPMAS system. The screen of a typical VDU is 24 lines (rows) by 80 columns, with a cursor and capability to internally store a fixed number of lines of data. The amount of internal data storage provided determines the extent to which paging and/or scrolling techniques will be provided. This "typical" VDU, for purposes of discussion, will be equipped with a keyboard. The keyboard will be assumed to include all the standard teletypewriter alphanumeric and control keys, and also a special set of keys for cursor movement and editing control. The assumptions being made here to include memory and special edit and control keys as part of the VDU (Keyboard Display Unit, in actuality), are an effort to reduce the complexity and amount of software required to be performed by the Man/Machine software at the CPMAS Station Control Position. A VDU including these types of characteristics to some extent is considered an "intelligent" terminal, where the amount of "intelligence" is directly proportional to the numbers and complexity of functions which can be performed by the terminal device itself.

For our "typical" terminal, when an operator types a character it appears on the screen at the position indicated by the cursor. In a normal terminal operating mode, the cursor will then automatically move one (1) position to the right, or, if at the end of the line, move to the first character position of the next line. If the VDU operates in a protected mode format, part of the screen is filled with characters displayed by the system, and blank areas are left for the operator to fill with characters. This "protected" mode of VDU operation will be used to reserve a high priority system notification area at the top of the display screen. The operator is prevented from entering characters into this area of the screen, thus reserving it for output by the system to notify the operator of important system events. This protected mode format is also used for efficiently accepting operator inputs using pre-specified forms. Since the cursor can only move within the unprotected areas (screen locations), the cursor will move automatically from input field to input field when filling in the pre-specified forms.

As a result of an analysis of the functions to be performed by the Station Controller operator, GTE Sylvania has defined a Command/Request language which will simply and efficiently permit the Station Control Tech Control Operator to use the system. The commands/requests contained in this language are English words intimately related to the function they perform. In addition to the English language commands/requests, the language is designed for ease of software implementation. Each command/request (designator) consists of four (4) to seven (7) alphabetic letters, with the first two of each being unique. Thus, the decoding logic for software recognition of the commands/requests requires a scan on only the first two character positions. The Tech Control Operator has the option of entering (inputting) from two up through the last character of the command/request, and having the system accept the act on the input.

A preliminary set of commands is presented in Table 7-8, and those with subfields are further described in subsequent paragraphs.

REQUEST

The REQUEST command permits the operator to request information from the NCS which is not CPMAS-D status related. The information which can be

Table 7-8

STATION CONTROLLER MAN/MACHINE KEYBOARD COMMAND/REQUEST

Command Designator	Designator Subparameter Var.	Function
STATUS	Identification, Equipment	Display Specified Status
REQUEST	Identification, Data Type Results	Request Specified Information Display Message to be Transmitted From Site to Station Control
MSGENR	Identification, Message Type	Initiate Message Entry
DELETE		Delete a Message Being Prepared
MODE		Initiate Specified Operating Mode at Station Control
PRINT		Initiate Hardcopy Displays of CRT Screen
NOPRINT		Terminate Hardcopy Display Function
DISPLAY		Initiate Display on CRT. When Display Information has been received at Controller. This input is in response to a system notification displayed in the high priority area of the VDU.
RUN		Re-initiate Execution of Station Controller Operation from Power Up Sequence
HALT		Stop Station Controller Operations

requested includes a variety of topics:

a) Connectivity Data
b) Fault Summary Information
c) Detailed Fault Displays
d) Alternate Routing Information
e) Nodal System Summary Displays
.
. etc.
.

In general, the Station Controller shall be capable of "REQUEST"ing any information which is maintained at the Nodal Control Subsystem, and conceptually could be extended to any other CPMAS element. Responses to these "REQUEST"s are in the form of messages to be displayed on the Station Controller VDU.

MSGENR

The MSGENR command/request permits the operator to create a free format message to be transmitted to another CPMAS station for display on a VDU and/or Hardcopy Device. The information contained in this message can be as desired by the operator. In this way, operators within the system may formally request information from other operators. Responses to these messages, once transmitted, are manually generated by operators at other CPMAS sites. Responses are in the form of messages to be displayed on the System Controller VDU.

Implementation of this command/request will require a specified protocol between the operator and the software to indicate when the complete message has been input. This can be accomplished by software only, or with the aid of hardware attached to the VDU.

STATUS

The STATUS command designator allows the operator to request status from any of the CPMAS elements with which the Station Controller can communicate. These CPMAS elements include the CPMAS-D and Nodal Control Subsystem directly (via CIS), and other Station Control or Sector Control sites using the Nodal

Control Subsystem as a relay station. The operator will be allowed to request any type of status information about any transmission equipment by specifying the CPMAS element identification and the transmission equipment status desired. The CPMAS element identification could include the station control element itself, thus requesting information about its own equipment which is checked by the self-test function. This is a special case for the use of this command, since the equipments are transmission equipment monitored by the CPMAS-D. An example of this command is:

STATUS NCS, RADIO

STATUS SELF (Special case for self-test status)

Response to the STATUS command/request is a message containing data which is fitted into the appropriate slot in the pre-formatted display skeletons maintained in the Station Controller Data Base.

7.4.2.3.4 Message Preparation

The Station Tech Control operator(s) will be provided with the capability of preparing messages. These messages can be addressed to the Nodal or Sector Control Subsystems or another Station Control Position via a Nodal Control Subsystem. The message preparation requires operator input of the destination address and the text of the message. The operator will be prompted to input the destination address and text. The text (message content) will be entered by the operator in free format with no software checks performed on the content of the text. The software will be required to format the input message into the communication line protocol format for transmission to the addressed CPMAS site. The message characters will be transmitted exactly as received from the keyboard with no character code conversion. Any required code conversion due to the nature of the display device at the destination address will be performed at the Nodal Control Subsystem. The Station Control Position software will, however, compress the input characters in order that the communication channel capacity is used to the maximum extent possible. Compression of the display characters involves appending multiplication factors to sequentially repeated characters. This is extremely useful when a considerable number of blanks (spaces) are left at the end of lines when the operator is composing the text of a message which will be displayed on a Visual Display Unit at another CPMAS site.

7.4.2.3.5 Received Traffic Processing

The Station Control Position will be capable of receiving message traffic from the Nodal Control Subsystem and the CPMAS-D. The Station Control Position software will process all received traffic to determine what type of data is contained in the received traffic. In addition, the receive processing software will strip off the protocol required overhead characters used by the system line protocol, and format the actual received message data characters for use by the Station Control received message effectivity processing. The following paragraphs describe the receive processing required as a function of the message transmitting site.

7.4.2.3.6 NCS to Station Control Position Message Processing

Traffic received at the Station Control Position from the Nodal Control Subsystem is classified in three major categories: Display Messages, Request Messages, Command Messages.

7.4.2.3.6.1 Display Messages Received from NCS

The majority of anticipated traffic will fall into this category. These messages contain information which is to be displayed on the Station Control Tech Controller's VDU. The messages are transmitted across the communication channel in the block format as specified by the specified line protocol. The software at the Station Control Position will be responsible for:

a) Determining What Type of Data is being received (i.e., Display, Message)
b) Stripping off the block protocol (overhead) characters and assembling the data characters into a message
c) Determining when the complete message (sequence of blocks) has been received
d) Expanding the Received Data into a format suitable for display on the VDU. The VDU Display Data will be compressed when formatted for transmission across the communication channel, to maximize use of the available channel capacity and minimize the transmission time of the message.
e) Set up a notification for high priority area of the screen, to inform the operator a message is ready for Display.

Messages in this category include all commands originated at the NCS and/or all messages (commands/requests) originated at any site and relayed to the Station Controller Position via the Nodal Control Subsystem. The responses, if any are required, will be manually prepared by the Station Controller operator (Man-Man), after viewing the displayed message.

7.4.2.3.6.2 Request Messages From NCS

These messages fall into the category of the NCS requesting Station Control Position resource status data. The type of data requested would probably fall into the facility to facility protocol message category. The specific messages and their content will be specified by the selected protocol; however, they would request information related to Station Controller resource allocation such as:

a) How busy are you (i.e., Real Time Utilization)
b) How much buffer space do you have available

.
.
.

These status requests are facility to facility and do not require operator intervention for a response. The receive message processing will be capable of:

a) Determining this type of request message
b) Stripping off the block protocol overhead characters and assembling the message
c) Determining when a complete sequence of blocks has been received containing the message
d) Analyzing the received message to determine what is being requested
e) Selecting the appropriate effectivity processing routine for received request message.

7.4.2.3.7 CPMAS-D to Station Control Position Message Processing

Traffic received at the Station Control Position from CPMAS-D contains the status information as monitored by the CPMAS-D. Since CPMAS-D transmits information by exception only, the receive processing software at the Station

Control is responsible for updating the CPMAS-D status data base maintained at the Station Control. The receive processing software will always inform the Station Control operator of a CPMAS-D reported change in status on an equipment basis, by printing an informational status message on the hardcopy device. Once a fault has been reported via the hardcopy device, all subsequent faults requiring printouts relating to faults on the same piece of equipment, will be suppressed by the software. Thus, if the Station Control Position receives a message from CPMAS-D reporting a fault in the Radio, the software will update its data base appropriately and automatically print an informational status message informing the operator that CPMAS-D has reported a radio fault. Should the Station Control Position receive any additional CPMAS-D message traffic reporting a fault in the same radio, the software will update the CPMAS-D data base; however, the informational status message will not be printed (i.e., suppressed), since the radio fault had been reported (printed) when the first status change message relating to this radio was received.

The software which processes CPMAS-D message will time stamp, to the granularity provided by the timing system, the arrival time of the reported CPMAS-D status changes maintained in the data base. These times will be provided in each status printout provided.

7.4.2.3.8 Station Control Position Communication Interface Processing

The Station Control Position will perform the same communication interface processing software as performed at the Nodal Control Subsystem, Sector Control Subsystem and higher echelon Subsystems. The specified line protocol will be common throughout the entire CPMAS system. The facility to facility type of protocol messages may be different between the various system hierarchical levels, but the line coordination protocol will be identical.

At the present time, the specific line protocol has not been specified; however, for purposes of discussion, it is assumed that whatever line protocol is selected, it will possess the following general characteristics:

a) Data (message) Characters will be framed within a set of Line Coordination protocol specific framing characters. The messages will

be segmented into these framed blocks for transmission across the communication channel, as shown in Figure 7-32.

The number of framing characters in the header and tail position and their specific contents will be specified by the selected protocol.

b) The Block Header framing characters will contain information relating to the originating site, destination address (site), segment (block) number within total number of message segments comprising the whole message, and type of characters contained within the block.

c) Depending on the complexity of the protocol (i.e., to accomplish priority or per-emptive communications), the header information could be extended to contain information relating to the message sequence number, number of times the data block has been re-transmitted, and a variety of other informational possibilities.

d) The Block tail framing characters will contain a specific (unique) character representing (or referencing) End of Data Block, and a Parity Character or sequence of parity characters. The sequence of parity characters, if selected, may represent an error detection correction character sequence for the block.

e) Data blocks may be variable in length.

f) Data blocks must be Acknowledged (or non Acknowledged) by the Receiving site.

g) Acknowledgements (or Non Acknowledgements) will be transmitted across the communication channel as messages formatted in data blocks as shown above.

h) Messages may consist of a variable number of data blocks.

A line protocol for the Station Control Position communication channel, similar to the one described above, will be considered for purposes of discussing the software required to support the communication channel interface. The software must be capable of receiving characters on a character-by-character basis and building the data blocks. Once a complete block has been collected (buffered), the software will provide analysis to interpret the

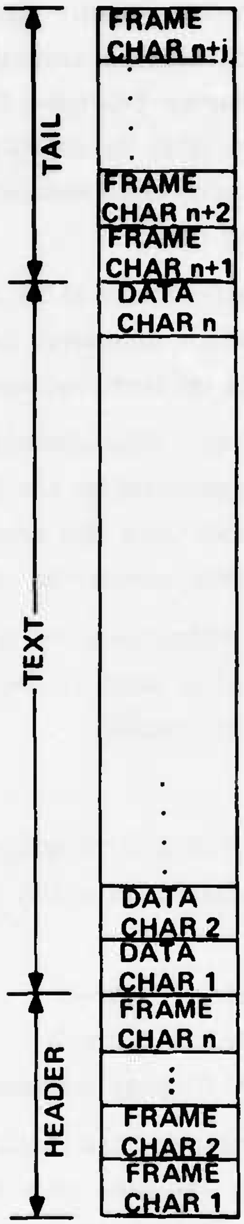

FIGURE 7-32. DATA BLOCK FORMAT

information contained within the header and tail portions of the block. In particular, the analysis software must determine the quality of the received data block by performing the block parity algorithm as specified by the line protocol for each received data block. If error detection/correction capability is provided for each data block, the communication interface software will include the bit correction algorithm. This bit correction algorithm will be performed whenever the specified parity check fails. This communication interface software will be capable of determining the required acknowledgement (or non acknowledgement) message to be generated for transmission to the transmitting site.

The header information characters will be analyzed so that message segments of the same message can be assembled into complete messages and passed to routines which operate on received messages.

On the other side of the coin, this communication interface software must be capable of taking messages generated by the Station Control Position, segmentizing them into data blocks with the appropriate block header and tail information, and transmitting them across the communication channel.

Although not a functional requirement of the communication interface software per se, this software will provide the buffering scheme to insure data is not lost (missed) for any reason.

7.4.2.3.9 Hardcopy Device

The CPMAS Station Control Position is equipped with a hardcopy device for permanently recording system information which is of interest to the operator. This information includes:

a) Status changes reported by CPMAS-D
b) Requested Status from Nodal Control
c) Hardcopy of present VDU display contents.

The software required to support this device will be capable of formatting the output for the device. This includes code conversion of characters if the character set for the printer is different from that specified for the display. In addition, this software will be responsible for inserting the line control characters (i.e., Carriage Return and Line Feed) required for presenting a display which is the image of a VDU display.

This software must, of course, provide the interface control (driver) software whose size and complexity are a function of the processor and hardcopy devices selected.

The only other function which the hardcopy device software must provide is the buffer space required to queue a sequence of hardcopy outputs. As previously identified, the software will automatically suppress printouts of CPMAS-D detected faults in the same piece of equipment once the first fault has been printed. The only other printouts which are generated are manually requested by the operator, and the software will control the rate at which these printouts can be requested. These techniques will help to reduce the buffering space required by the Station Control Position for printout (hardcopy) purposes.

7.4.2.3.10 Station Control Position Data Base

The Station Control Position data base is divided into two (2) parts, static (constant) and dynamic data. The dynamic data consists of data which is updated (modified) during the normal course of Station Control Position software execution and data which is not normally updated during the software execution, but rather is capable of being modified by the operator via a keyboard input command or request. Dynamic data in the latter category includes threshold and count data. The Station Control Position software will normally use a threshold or counter stored in the data base as a constant in the performance of a function. If the operator has the ability to change these values, for whatever reason, the software will operate using this modified value. These parameter values are "dynamic", in this sense, as opposed to continual change during the normal course of the Station Control Position software execution. Various types of status tables and variables are dynamic in the sense that they are updated by the software during the normal program execution. The static data consists of constant data items which will never be allowed to change once the software has been developed. In general, these data base items will consist of internally used (to software) buffer pointers and parameters specific to the internal workings of the software, rather than any functionally related system parameters.

The Data Base maintained at the Station Controller site is a major (driving) factor, if not the major factor, in determining the extent of processing required at the Station Controller, and, to some extent, the processing required at the sites interfacing with the Station Controller. As described in Section 7.4.2.3.11, the Station Control Position will be capable of operating in a minimum of two operating modes: Normal (NCS available) and Stand Alone (NCS unavailable). In order to determine the software functions required and estimate the size of the memory storage required, a description of the presently identified operating modes has been provided in Section 7.4.2.3.11. Regardless of operating mode, the following data items will be maintained at the Station Controller:

a) Data Relating the Analog Values per Equipment Type to the Threshold for each Severity Indicator (i.e., RH, AH, RL, AL)

b) Data which relates the Analog Alarm value per equipment to the conversion routine for display

c) Display formats (skeletons) per equipment type

d) Dynamic Data which maintains a record of equipment (not equipment types) which is reported as faulted

e) Data which relates equipment(s) at a station to its specific equipment type

f) Data which relates each equipment type with the positional location of the corresponding status data in the total bit stream of status data

g) Input/output Channel Block Buffers

h) Visual Display Unit Display Buffers.

The data presented above represents the minimal set of data which must be maintained at the Station Controller. It is at this point that the software tradeoffs can take place, which involve trading off data base storage equipment processing functions.

7.4.2.3.10.1 Data Base Consideration for CPMAS-D Equipment Configuration

It is immediately obvious that the above specified minimal data base

does not maintain data which defines the equipment configuration being monitored by the CPMAS-D. If the operator at the Station Controller wishes a status display of the equipment configuration, which would probably be one of the first requests in the Stand Alone mode, the Station Controller software will respond to this request by preparing a fixed status request message, transmitting it to the CPMAS-D, waiting for the reply with the configuration data in it, receiving response, processing this particular response message, and finally incorporating the received status data into a formatted skeleton for VDU display. The response time to perform this operator request is, at a minimum, the time required to send a message in each direction, plus a processing time delta which is probably insignificant compared to the time required for the inter-CPMAS site communications. As presently identified, the minimum response time for the sequence of events described above will be 2 times the Station Controller position to CIS communication time, plus 2 times the CIS to CPMAS-D communication time per data block.

If the Station Controller were to maintain its own copy of the configuration data base (maintained at the CPMAS-D), then the status display request becomes a simple task, and the response time is almost immediate in terms of human reaction time, since the required data is in the memory store of the Station Controller Position. The software processing at the Station Control Position will, in this case, be required to process all NCS to CPMAS-D and/or Station Control traffic to check for traffic commanding equipment switchover. This CPMAS-D data will have to be initialized at the Station Controller Position on startup by requesting the information from either CPMAS-D or the NCS and automatically updated by the software as a result of inspecting all traffic to/from the CPMAS-D. This, of course, imposes requirements on the CIS to insure that NCS to CPMAS-D traffic is also routed to the Station Control Position, or, alternatively, the CIS is required to "filter" the data and route only appropriate data to the Station Controller.

7.4.2.3.10.2 Data Base Consideration For CPMAS-D Equipment Status

The minimal data base does not include a copy of the CPMAS-D status data. Whenever the operator requests the status of a specific piece of equipment,

the Station Controller will execute the same functional sequence of operations, as described above, in communicating with another site (CPMAS-D or NCS) to obtain the information. In this case, the information requested may require more than one block's worth of data to be transmitted back to the Station Control. This results in a response time double that identified in Section 7.4.2.3.10.1.

7.4.2.3.11 Operating Modes

The Station Control Position software will be capable of operating in three presently identified operating modes. These three modes will be specified as Normal, Mode 1 (Stand Alone), Mode 2 (Special).

The Normal Mode will provide capabilities as described in Paragraphs 7.4.2.3 through 7.4.2.3.9. The Stand Alone (Mode 1) operating mode becomes effective when the Station Control Position software detects non-existence of the Nodal Control Subsystem. The Special (Mode 2) operating mode will become effective when the Station Control Position software receives a command from the Nodal Control Subsystem to enter this operating mode.

7.4.2.3.11.1 Station Control Position Stand Alone Operating Mode

The Station Control Position software is required to continually check for the availability of the Nodal Control Subsystem when operating in the Normal or Special Operating Modes. The procedure required to determine this condition is part of the selected protocol (facility to facility protocol). Once the non-availability of the NCS is detected (regardless of present operating mode), the Station Control Position software will automatically enter the Stand Alone operating mode. Operating in this mode requires the Station Control Position to be capable of expanding its functions so as to at least partially compensate for the non-availability of the NCS.

In this regard, the Station Control Position software will allow the operator an extended set of functional capabilities by allowing an extended set of keyboard commands requests to be processed. When operating in this stand alone mode, the software will:

a) Allow station control Threshold and Counter Modification not allowed in any other operating mode

b) Allow Redundant Equipment Switching capability on operator request

c) Allow for special message preparation and transmission to the CPMAS-D commanding special diagnostic routines to be exercised

d) Perform processing to determine the NCS availability

e) Suppress transmission of operator prepared messages to NCS (which is unavailable).

7.4.2.3.11.2 Station Control Position Special Operating Mode

The Special Operating mode of the Station Control Position software will be entered as a result of receiving a message from the NCS commanding the Station Control Position to execute in this mode. The functions performed in this mode are an expansion of those performed as part of the Normal operating mode, and a subset of those functions allowed in the Stand Alone operating mode.

In this mode, since the NCS is still available, the Station Tech Control operator will not be permitted to modify thresholds and counters; however, the operator will be allowed access to that set of keyboard input commands/ requests which allow generation of messages commanding the CPMAS-D to perform specified diagnostic routines and return specified equipment status. The returned status will be displayed, and the operator will be allowed the capability to switch on redundant equipment(s). This mode will provide the Station Control Position the capability of performing the fault detection and reporting functions, without involving the NCS. The Station Control Position software will not perform fault isolation comparable in any way to that provided at the NCS.

7.4.2.4 CPMAS Communications Interface Set (CIS) Software Functional Design

7.4.2.4.1 CIS Function Description

The Communications Interface Set (CIS) unit is a communications controller which interfaces the Nodal Control Subsystem (NCS) with subordinate stations allowing the transfer of information between sites. The CIS element acts as a go-between in transferring information between the NCS and its

subordinate sites, and Station Control and CPMAS-D elements (see Figure 7-33). CIS does not perform any modification to the data it receives; it simply outputs the received data to its addressee (CPMAS-D or Station Controller). The type of information passed through the CIS includes any data which can be transferred between sites. As shown in Figure 7-34, the CIS interfaces with CPMAS-D, Station Controller and Nodal Control Subsystem processors. The CIS provides full duplex communications capability with each interfacing site.

This section will present a description of the software required to perform the CIS interface function. A software family tree is presented as a point of departure for discussing each functional module of this software system.

7.4.2.4.2 CIS Communication Interface

The Communications Interface Set (CIS) software functions provide support in the following four areas:

a) Communication Channel Interface
b) Data Block Processing
c) Self Test
d) Buffer Management

The communication channel interface software will provide the CPMAS CIS unit with the capability to communicate with the Nodal Control Subsystem, CPMAS-D, and/or the Station Controller position. As specified for the Station Controller and Nodal Control Subsystem, this communication interface software will be developed to support either asynchronous or synchronous mode of operation, depending on which is specified. This communication channel interface software will support the functions as described in the hypothetical protocol procedures described in Section 7.4.2.3.8.

7.4.2.4.3 Block Processing

The CIS software will be capable of receiving characters on a character-by-character basis and building data blocks. The data characters will be accumulated (buffered) into complete blocks as specified by the selected protocol. The assembled blocks will then undergo analysis processing. This

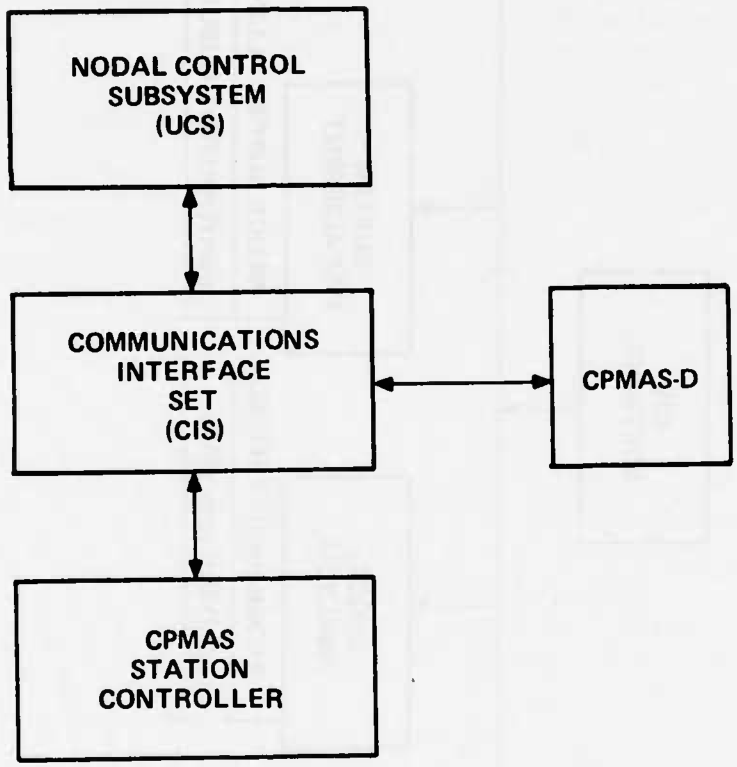

FIGURE 7-33. CIS OPERATION

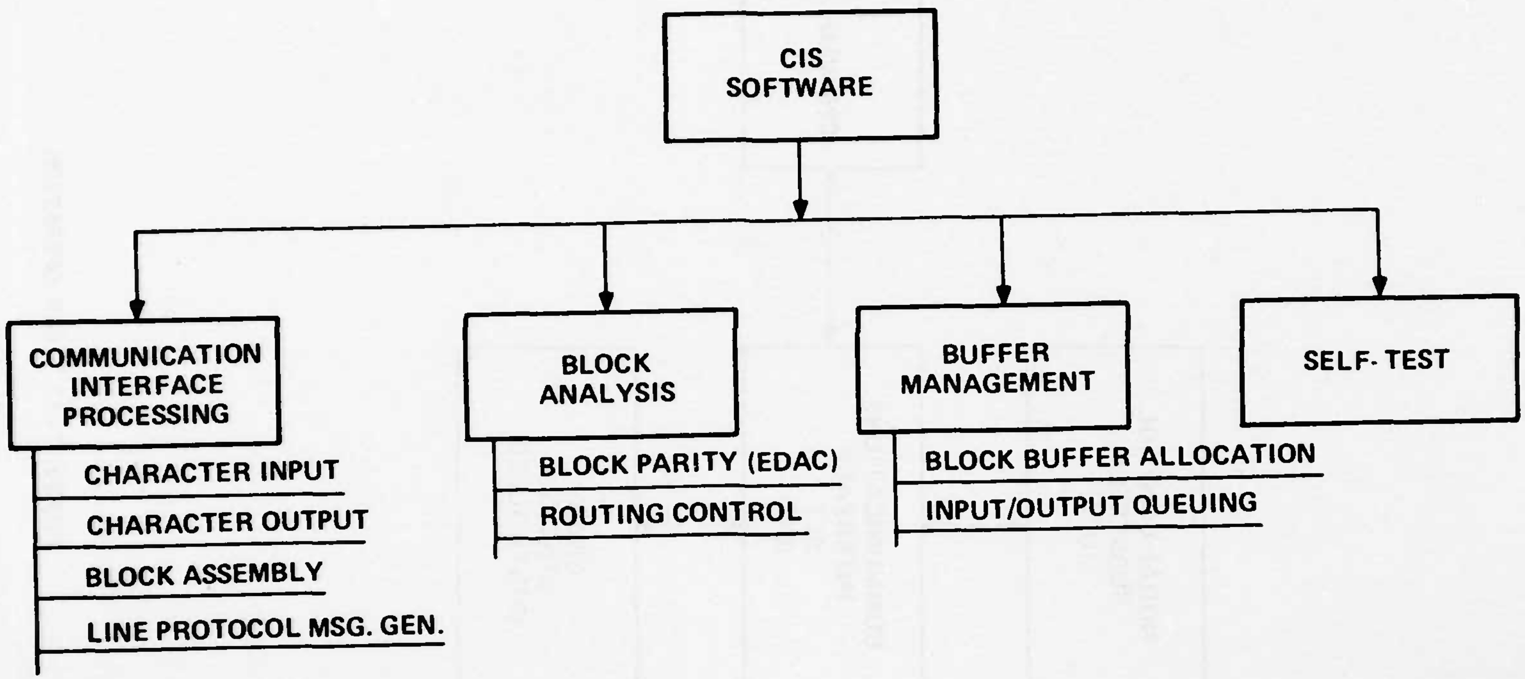

FIGURE 7-34. CIS SOFTWARE FAMILY TREE

software will interpret the information contained within the header and tail portions of the block. This data will be used to verify the validity of the received data block. A block parity algorithm, as specified by the line protocol, will be performed on each received block. If an error correction algorithm is provided, it will be performed whenever the specified parity check fails.

Another aspect of block processing is the Routing Control function. This function will be responsible for selecting the appropriate output line queue for each data block. This will be accomplished by analyzing the destination address information contained within the block header and translating this into an output line queue. In the case of data block(s) received from the NCS and the Station Control Position, the routing information will be analyzed to determine the block(s) destination, and the block(s) are queued for output to the appropriate destination. In the case of block(s) input from the CPMAS-D, however, the procedure differs. Hence each CPMAS-D block will be re-formatted, and duplicate block(s) (with updated routing information) queued for output to both the NCS and to the Station Control.

This capability will provide the Station Controller and NCS position with all CPMAS-D status information simultaneously as it occurs. This will help to limit the messages from the Station Control Position to the CPMAS-D and/or NCS, requesting CPMAS-D data.

7.4.2.4.4 Buffer Management

This software will coordinate and control the buffer allocation for each input and output part. Incoming data characters will be buffered to assemble the entire data block for subsequent block processing. The input buffer size requirements are a function of communication line speed, traffic loading, and protocol requirements. At this time, the buffering requirements at the CIS do not appear large. A double block buffer for each input/output port may suffice. Detailed analysis will be performed when the related parameters are specified.

In addition, this software will control the input/output queues used for data block routing. The software will provide the means to link, add and delete queue entries.

7.4.2.4.5 Self Test

The CIS software will provide the mechanism for self test. Periodically, the software will exercise a pre-defined set of functions on a time available basis to verify proper operation of the CIS module. In addition, the software will exercise the interfaces to the NCS, CPMAS-D and Station Control positions. Errors detected will be recorded, and error reporting software will facilitate operator notification at both the NCS and the Station Control Position.

7.4.2.5 Sensitivity Analysis of Station Controller and CPMAS-D Software

This section will address software sensitivities associated with the CPMAS-D and the Station Controller Position. The analysis presented here will demonstrate the effect the site of the transmission system has on the CPMAS-D and Station Control Position storage. Both the station size and the nodal area size will be varied. The effect on the storage size by varying the type of transmission equipment will also be shown. The analysis will include the DRAMA, FKV and DAU/FM radio system. The effect on the CPMAS-D scan speed of varying the size of the station will also be shown.

In the analysis to follow, the equipment is assumed to be configured as defined in the CPMAS model. In each case, it is assumed that all available monitor points are used. This by no means implies that all points will be used or even recommended in the final system. The total set of monitor points was used solely to provide a baseline for the storage analysis. As the number of monitor points selected varies, the storage requirements will change accordingly.

In addition, it should be noted that the storage estimates do not include either program or communication interface storage. The program storage requirements are relatively static and are not significantly sensitive to variations in either type or number of radio systems. Similarly, the communication interface storage is primarily derived from the protocol requirements and is relatively insensitive to type and number of radio systems monitored.

7.4.2.5.1 Station Control Data Storage Vs. Number of Radio Systems

The effect on the Station Control position storage requirements as the number of radio systems increases is shown in Figure 7-35. For this analysis, the DRAMA radio system as defined in the CPMAS model was used. Each radio system includes 1 radio, 1 service channel multiplexer, 1 second level multiplexer, 1 KG-81 cryptographic unit and 8 first level multiplexers. The non-zero origin of the curve is attributed to overhead storage that is independent of the number of radio systems supported. A major portion of this static storage is the display formats necessary to support the Station Controller function.

A significant portion of the data storage, however, is directly related to the size and number of radio systems at the station. This data includes Analog and Count parameter thresholds, station equipment lists, data-to-support parameter conversion functions and other equipment related storage. In this analysis, such storage was found to be 213 Bytes of data per radio system. As seen in Figure 7-35, the combined storage required for a one radio station is approximately 3,000 Bytes, while the storage required for a 16 radio station is more than 6,000 Bytes. The increase is attributed directly to the increased station size.

7.4.2.5.2 CPMAS-D Storage Vs. Number of Radio Systems at the Nodal Station

The effect of varying the number of radio systems at a Nodal Station and of varying the number of first level multiplexers within the systems has on CPMAS-D storage is shown in Figure 7-36. The basic Nodal Station is characterized by 2 radio, 2 service channel multiplexers, 3 KG-81 cryptographic units, 3 second level multiplexers, 12 first level multiplexers and 12 sub-multiplexers. The storage required at the CPMAS-D includes a complete data base of monitor data, threshold data to facilitate exception processing, status monitor control data and other equipment related storage. The effect of the first level multiplexer terminations is evident. As seen from the family of curves in Figure 7-36, at a 25% termination rate the CPMAS-D storage requirement varied from approximately 1,200 Bytes for a two radio

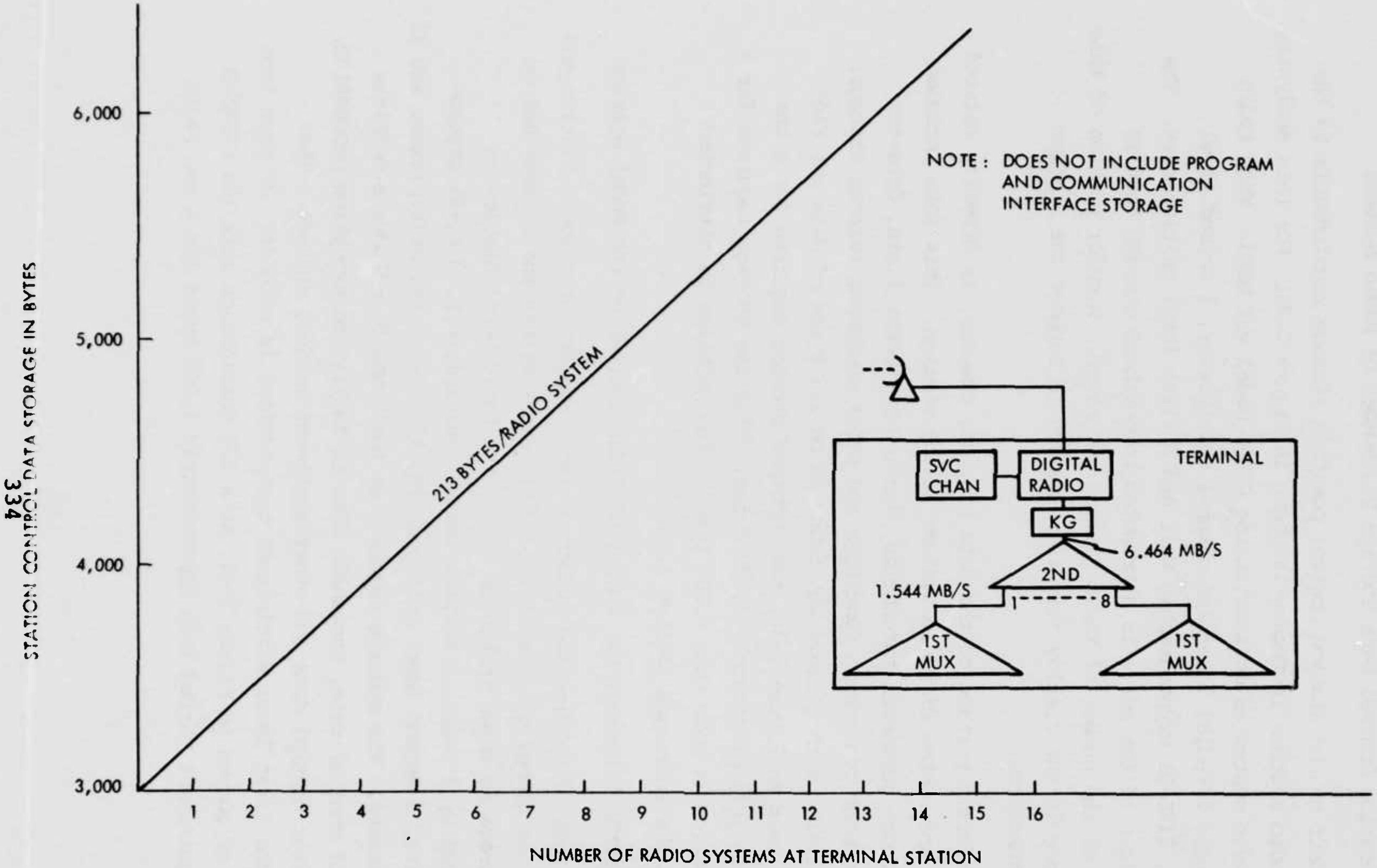

FIGURE 7-35. STATION CONTROL DATA STORAGE Vs. NUMBER OF RADIO SYSTEMS

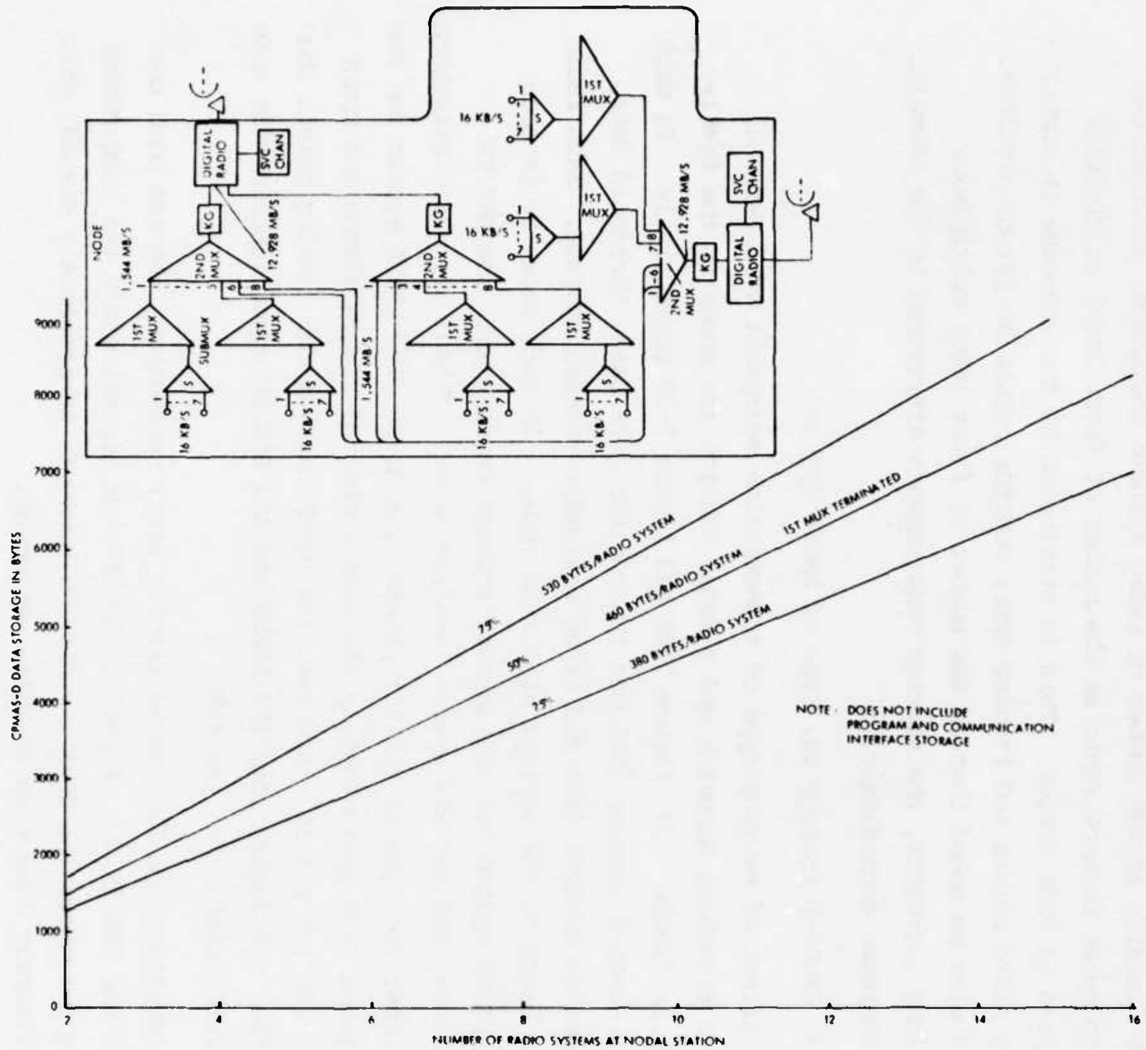

FIGURE 7-36. DPMAS-D STORAGE Vs. NUMBER OF RADIO SYSTEMS AT NODAL STATION

system to approximately 7,000 Bytes for a 16 radio system. At a 50% termination rate, the storage varied from 1,500 Bytes for a two radio system to 8,300 Bytes for a 16 radio system. Similarly, at a 75% termination rate, the storage required varied from 1,700 Bytes for a two radio system to 9,700 Bytes for a 16 radio system. In general, it is observed that the storage increases linearly as the number of radio systems increases, and that the rate in increase is more rapid as the number of first level multiplexer terminations is made larger. This is attributed to the increase in number of binary alarm points and framing error monitor points at larger stations. It should also be noted that as the number of first level multiplexer terminations increases, the storage requirements attributed to the submultiplexers increase accordingly.

7.4.2.5.3 CPMAS-D Storage Vs. Type of Radio System

The effect of varying type of transmission equipment at a Terminal Station, a Branching Repeater and a Nodal Station are shown in the family of curves in Figure 7-37, Figure 7-38 and Figure 7-39 respectively. In each case, the CPMAS-D storage includes the monitor data base, threshold data, status monitor control data and other equipment related storage. Each radio system is based on the appropriate CPMAS model. In each case, it is seen that the DRAMA system had the largest storage requirement, the DAU/FM required less, and the FKV system required least. This is primarily attributed to the number and type of monitor points available. The DRAMA system and the DAU/FM system have approximately the same number of Binary alarms and count parameter monitor points. However, the DRAMA has far more analog points than the DAU/FM. Similarly, both the DRAMA and the DAU/FM have significantly more binary alarm points than the FKV.

In addition, the FKV has no framing error parameters, whereas both the DRAMA and the DAU/FM do. Finally, the FKV has approximately the same number of analog parameters as does the DAU/FM; however, as previously stated, this is significantly less than in DRAMA equipment.

7.4.2.5.4 CPMAS-D Scan Time Vs. Number of Radio Systems at the Nodal Station

The effect on the CPMAS-D scan processing by varying the number of radio systems monitored at a Nodal Station is shown in Figure 7-39. For this

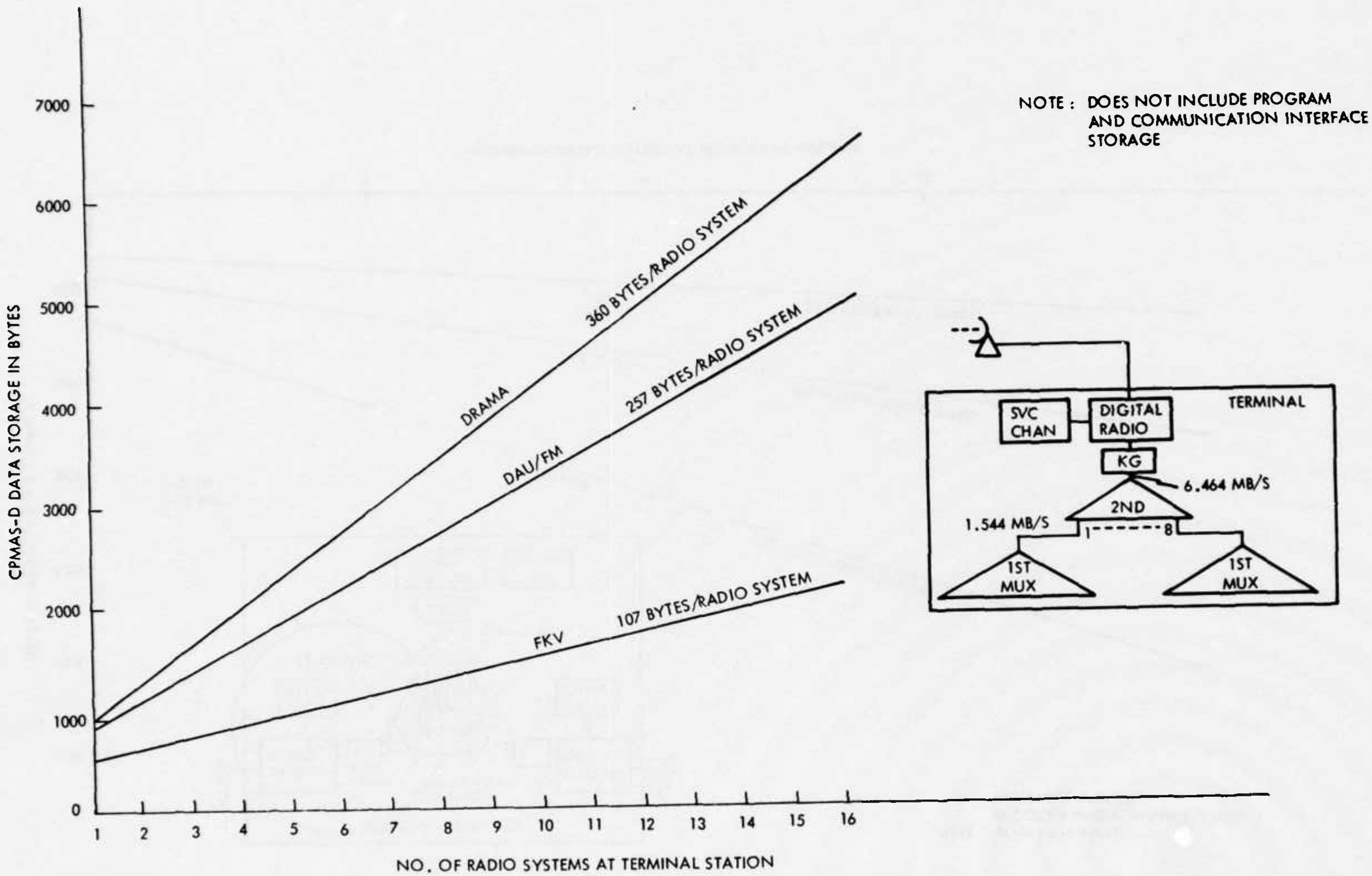

FIGURE 7-37. CPMAS-D DATA STORAGE Vs. NUMBER OF RADIO SYSTEMS AT TECHNICAL STATION

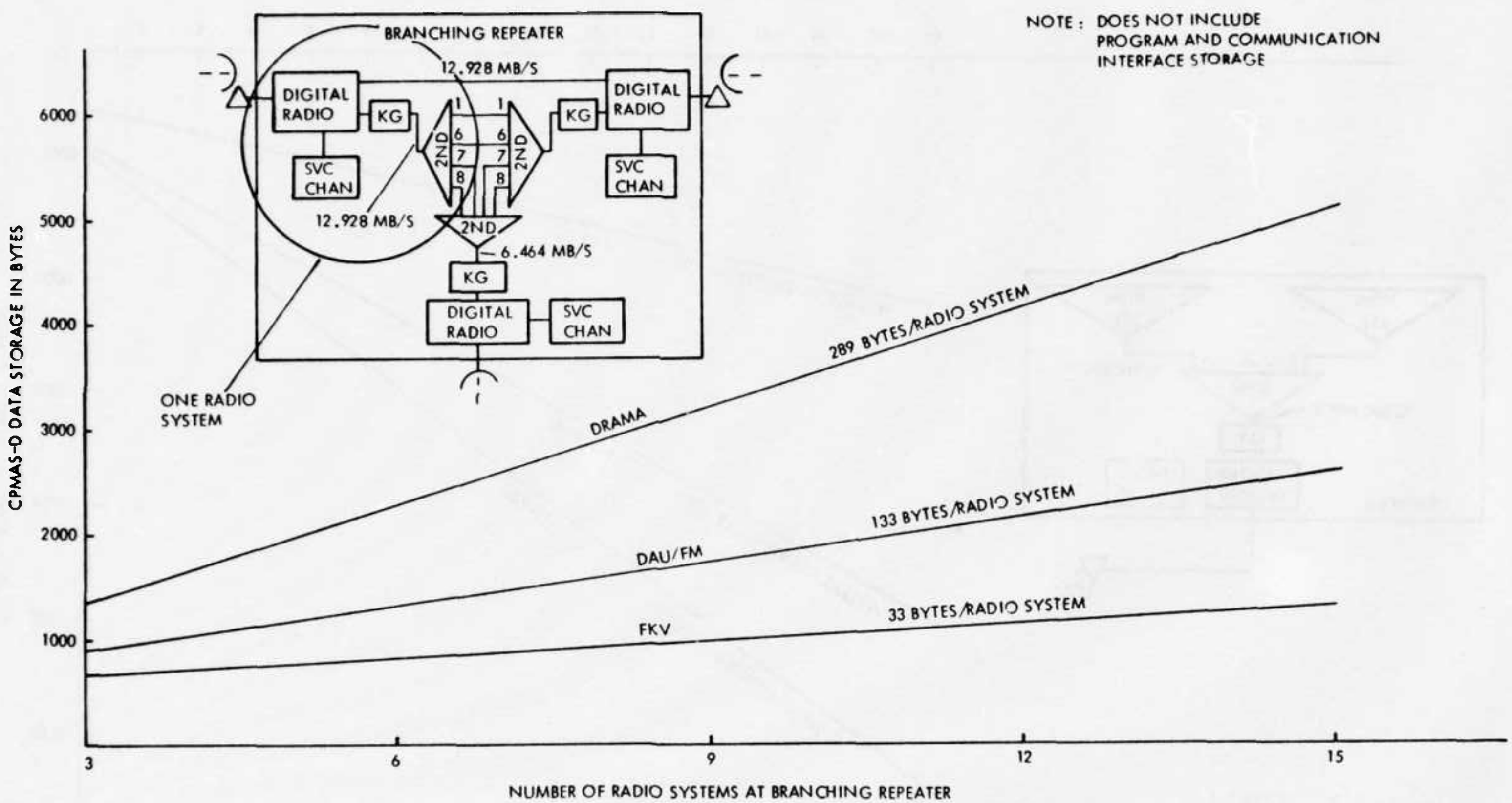

FIGURE 7-38. CPMAS-D DATA STORAGE Vs. NUMBER OF RADIO SYSTEMS AT BRANCHING REPEATER

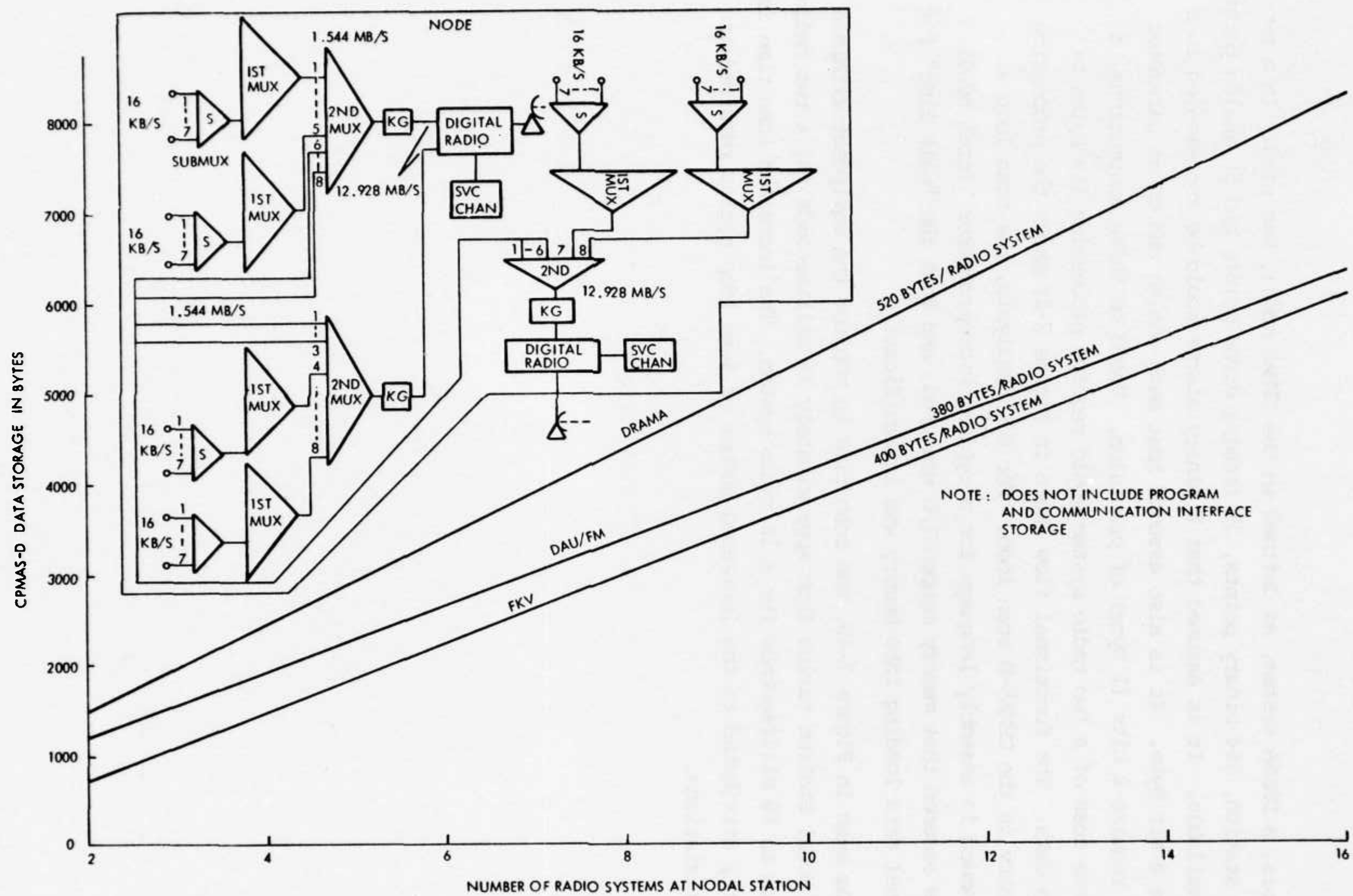

FIGURE 7-39. CPMAS-D DATA STORAGE Vs. NUMBER OF RADIO SYSTEMS AT NODAL STATION

analysis, a DRAMA system, as defined in the CPMAS model, was used. In a two radio station, 564 binary points, 39 framing error points and 56 analog points are available. It is assumed that 8 binary alarms would be represented in a single 8 bit Byte. It is also assumed that each analog and count parameter would require 8 bits (1 Byte) of precision. Based on these assumptions, a complete scan of a two radio system would require processing 169 Bytes of status data. The functional flow chart in Figure 7-28 shows the processing necessary in the CPMAS-D scan loop. For this analysis, the scan loop was programmed in assembly language for a typical microprocessor (Intel 8080). It was assumed that memory mapped I/O was used, and that the "wait time" for external data loading into memory was insignificant.

As seen in Figure 7-40, the scan time to monitor the equipment within a CPMAS Nodal Station varies from approximately 14 milliseconds for a two radio station to 58 milliseconds for a 16 radio system. The increased scan time is directly attributed to the increased number of scan loop cycles required at larger stations.

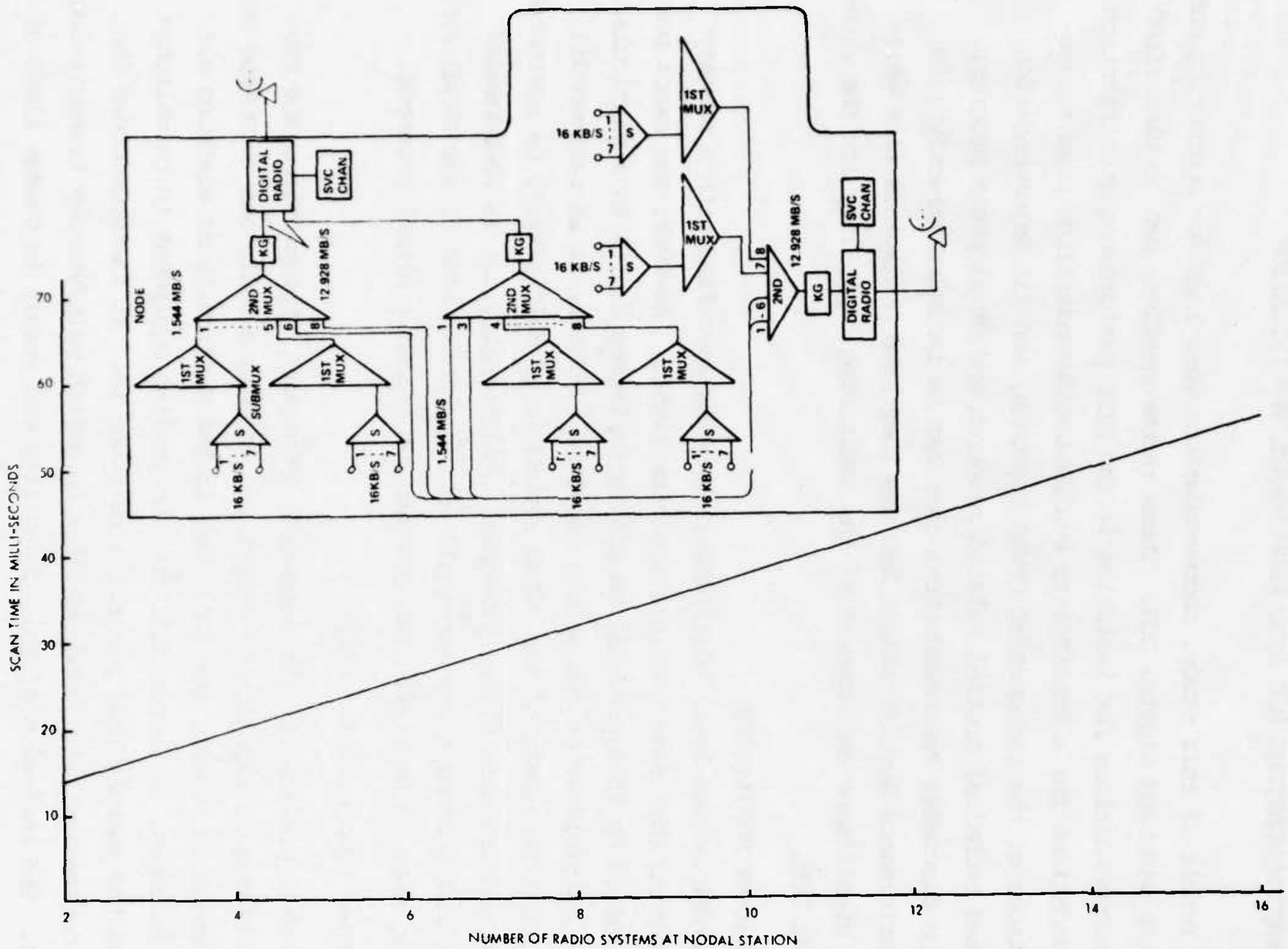

FIGURE 7-40. CPMAS-D SCAN TIME Vs. NUMBER OF RADIO SYSTEMS AT NODAL STATION

SECTION 8

RECOMMENDATIONS FOR ATEC PERFORMANCE SPECIFICATION

As a result of this study, recommendations were made for monitoring and assessing the wideband digital DCS. These recommendations can be classified as: (1) Recommendations for inclusion in the ATEC performance specification, (2) Recommendations for a feasibility evaluation/demonstration plan for selected portions of the recommended CPMAS approach, and (3) Recommendations for automated technical control related research and development programs. This section discusses recommendations that can be included directly into the ATEC performance specifications because they have negligible risk while yielding a significant enhancement of the monitoring capability for the wideband digital DCS.

8.1 Multiplexer Monitoring

The DRAMA second level multiplexer is being specified with a summary alarm indicating that some port has lost its signal. However, the exact port is not indicated by an alarm. As an aid in isolating faults to a particular first level multiplexer or the second level multiplexer, it is recommended that individual terminals of the DRAMA second level multiplexers be monitored for receive and transmit signal presence. Additionally, it is recommended that individual channel/group terminals on the channel side of the DRAMA first level multiplexer be monitored for receive and transmit signal presence.

8.2 Automated Equipment Switching

ATEC will provide for the automatic gathering, transmission, and processing of status information to detect and isolate a fault and recommend corrective actions to restore service. Due to the difficulty of alarming all equipment failures, it is possible for the on-line equipment to be malfunctioning and the standby unit not being switched in. It is recommended that the nodal controller have the capability to switch main/standby transmission equipments. The inclusion of this capability can result in outage times of a few minutes as opposed to the hours that may be required to restore service for an unmanned repeater station. This capability can also be used as a fault isolation aid by providing the additional information required to isolate a fault to a particular equipment.

8.3 Displays

The displays discussed in Section 6 will provide the nodal controller with information concerning the status and performance of the transmission equipment. This information can be used to aid in service restoral by efficiently presenting the monitored data. As the restoral actions will be initiated at the station level, it is recommended that the nodal control displays be made available to the station controller at the station control position. Enactment of this recommendation will reduce the display format processing required at the station level.

8.4 WDMS Data

The WDMS will gather and process data regarding the status of all wideband digital equipments at a station. This information will be transmitted to nodal control via the telemetry channel. The time to transmit the status information is dependent upon the telemetry channel rate, the amount of data, and the type of data coding (i.e., ASCII or binary). Binary coding is the form in which CPMAS data is accessed at the WDMS and stored and processed at the NCS. Thus ASCII coding for transmission over the telemetry channel would require binary to ASCII at the WDMS and the reverse conversion at the NCS. Also, binary coding provides more efficient and speedier transmission of data to nodal control. Therefore, it is recommended that CPMAS data from the wideband digital monitoring set be binary coded.

8.5 Telemetry Rates

The time to transmit a display from nodal control to station control is an important factor in the station controller's ability to accomplish rapid restoral and repair. In order to provide the nodal control displays to the station control position with acceptable waiting times, the nodal control to station control communications recommended rate is 2400 b/s.

8.6 Communications Interface Set

The communications interface set will combine the information from all the MAS elements at a station with the station-to-nodal control communications. With the transmission of display information necessitating a 2400 b/s communications rate from nodal control to station control and with the desire

to limit the telemetry channel rate to 2400 b/s to enable the use of 4 Khz voice channels, it is recommended that the CIS be a concentrator as opposed to multiplexer.

SECTION 9

CPMAS FEASIBILITY DEMONSTRATION PLAN (OPTION PLAN)

The CPMAS study phase analyzed the DCS digital transmission system and DCS digital transmission system requirements, evolved wideband digital CPMAS requirements, and recommended a general wideband digital CPMAS approach. Valuable ATEC engineering data and guidance made available by the government and government personnel complimented GTE Sylvania's design and analysis efforts during the CPMAS study phase and resulted in a sound, balanced digital CPMAS approach.

Certain critical issues which exist in the CPMAS approach as in any advanced system should be addressed in a feasibility testing program to guarantee success of the algorithms and techniques selected. The critical issues include performance assessment, fault detection/isolation and trending techniques for the new digital DCS and in particular performance assessment of high speed data signals at 12 Megabits per second.

The CPMAS option phase plan provides for performance verification of recommended CPMAS algorithms for digital transmission systems which include performance assessment, fault detection/isolation, and trend analysis. The CPMAS option phase plan further reduces development risk by in-plant and field testing of a feasibility model to insure algorithm performance objectives are satisfied in an operational environment.

Areas to be addressed by the Option Phase and the associated approaches will be:

. Comparative analysis of wideband digital performance assessment techniques.

- Compare Channel Estimation with the Eye Opening Monitor via in-house and field tests
- Test the performance assessment techniques for induced equipment degradations
- Determine the limitations of the techniques

- Assess the techniques as maintenance aids

. Determine Effectiveness of Trending for failure prediction

- Compare Exponential and Direct Smoothing as trending technique via in-house and field tests

- Assess the failure predictive capability of SNR, TSP, SDR and BER

- Test the trend analysis techniques for induced equipment degradations

. Evaluate the wideband digital fault isolation concept

- Develop the hybrid sequential/signature approach to fault isolation

- Test the fault isolation approach by inducing equipment failures and processing equipment and site alarms

- Assess space and time complexity of the fault detection/ isolation algorithm

Additionally, man-machine operations can be experienced by technical controllers at both in-plant and field tests. Nodal control and station control interaction can be experienced using the CPMAS evaluation model. CPMAS will utilize a Higher Order Language to facilitate program design and documentation and will determine its applicability to CPMAS and ATEC.

The CPMAS option phase program will:

(1) Develop and test WDMS algorithms and techniques,

(2) Perform early field test evaluation of performance assessment approaches,

(3) Implement and program a CMPAS test processor subsystem. The test processor subsystem will evaluate wideband digital CPMAS nodal control and station control functions and potential Higher Order Language (HOL) implementation. The test processor will also simulate digital transmission equipment faults and alarms for in-plant and field testing of CPMAS,

(4) Perform a field test site survey,

(5) Generate test plans for performance verification of all algorithms,

(6) Perform field test of CPMAS feasibility models at Fort Huachuca or other CONUS test facility.

It should be noted that the WDMS designed and developed is a feasibility model and is not meant to meet the wideband digital monitoring specifications of the ATEC system.

Benefits derived from the CPMAS option phase program include verification of the WDMS design and its performance at digital rates up to 12 Megabit/sec, remote control of digital transmission equipments by CPMAS and the technical controller as well as performance assessment in a real world transmission system environment. Nodal control software and data base architecture will be developed. Tested CPMAS algorithms for performance assessment, trending, and fault detection/isolation will be provided. Display formats for nodal control and station control, and man-machine interaction between the controllers and between the controller and the CPMAS processor will be optimized. The CPMAS test model will provide the Government with an operational wideband test facility which can be used to evaluate future ATEC enhancements and as a technical control training aid.

9.1 Program Description

The wideband digital CPMAS Option Phase will evaluate the recommended wideband digital CPMAS approach using the functional evaluation model shown in Figure 9-1. Feasibility models of the Wideband Digital Monitoring Set (WDMS) will be fabricated to demonstrate the CPMAS algorithms. Nodal control and station control CPMAS functions and simulation of the digital transmission system and Communication Interface Set (CIS) will be implemented in a test processor.

Figure 9-2, the in-plant evaluation model, indicates the test arrangement for in-plant testing of the wideband digital CPMAS. Two CRT/Keyboard terminals are used to emulate the station and nodal control display terminals. The test processor interfaces with the WDMS to receive and transmit WDMS to

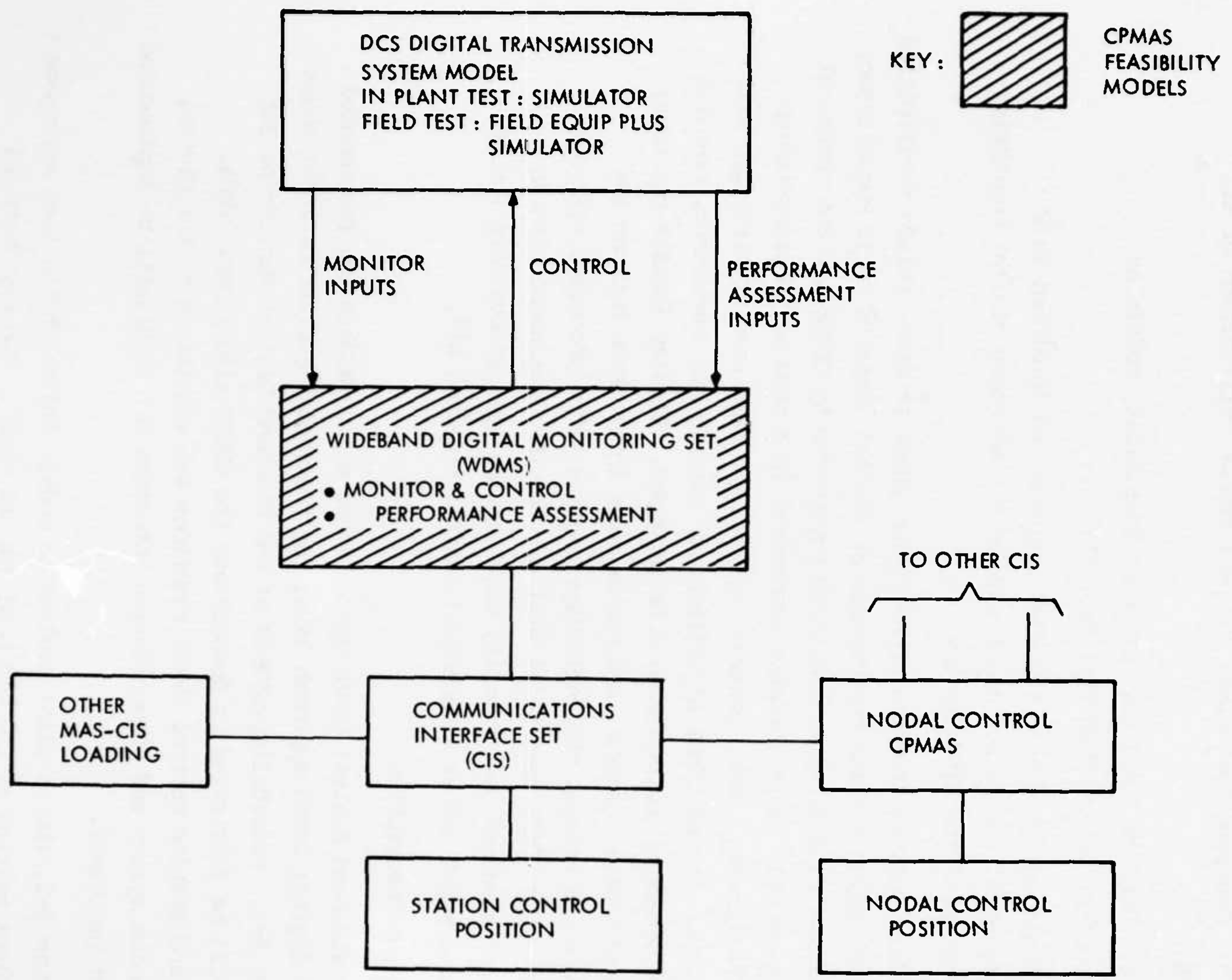

FIGURE 9-1. FUNCTIONAL CPMAS EVALUATION MODEL

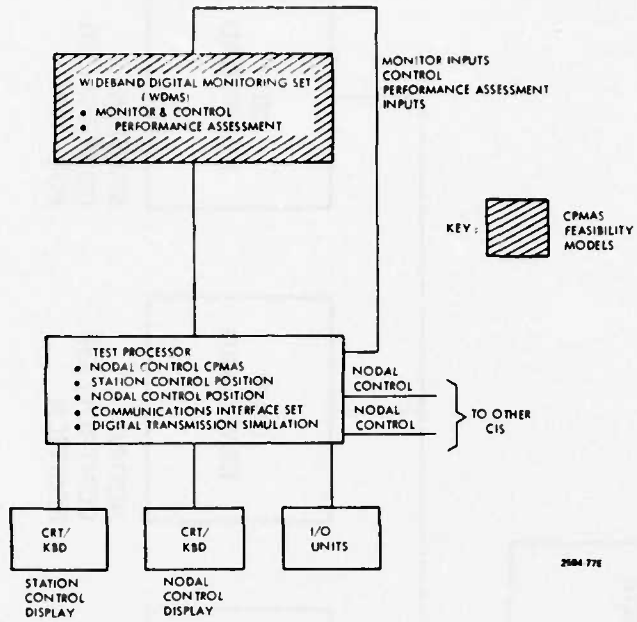

FIGURE 9-2. CPMAS EVALUATION MODEL

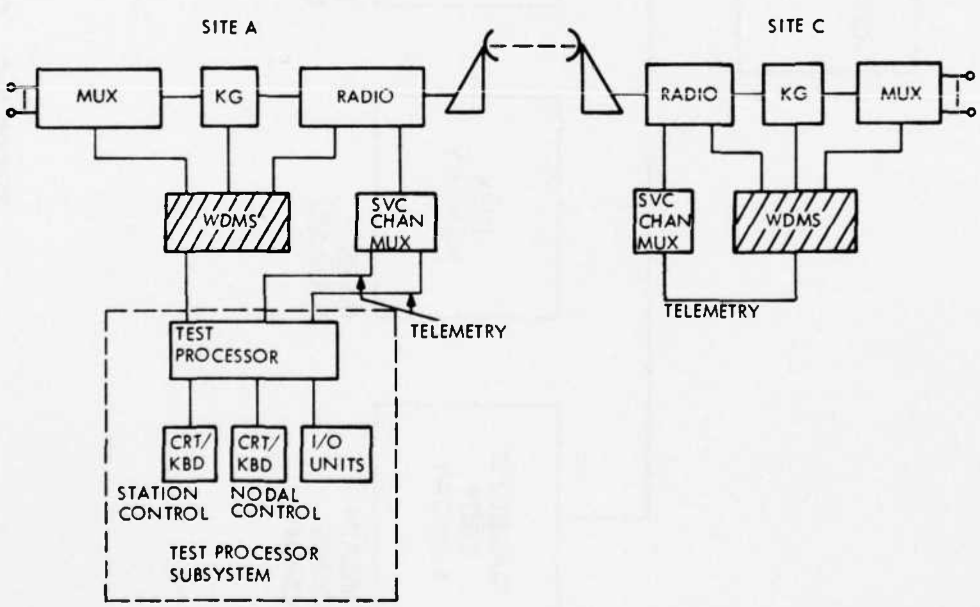

FIGURE 9-3. CPMAS EVALUATION MODEL FOR FIELD TEST

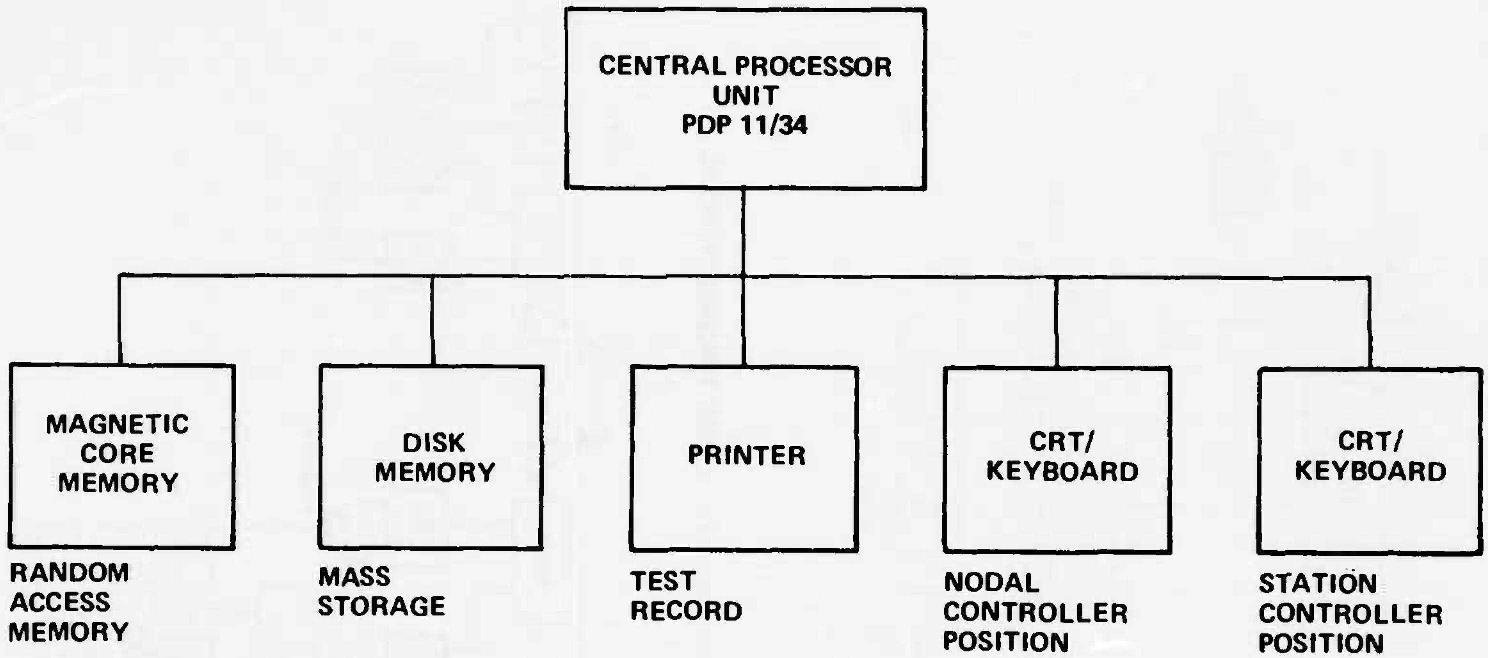

FIGURE 9-4. TEST PROCESSOR SUBSYSTEM

nodal control and WDMS to station control communications. The test processor simulates the transmission equipment's monitor and performance assessment inputs to the WDMS for in-plant evaluation and also for WDMS loading in field testing. The functions performed by the test processor subsystem include:

1. Implement nodal control wideband digital CPMAS functions,

2. Implement station control wideband digital CPMAS functions,

3. Simulate digital transmission equipment and Communications Interface Set (CIS),

4. Accept telemetry inputs from another station for implementing the two station field test models shown in Figure 9-3.

Initial software program design of wideband digital CPMAS and software test programs will be developed on GTE Sylvania's Phoenix Processing System. WDMS feasibility models will be fabricated and used with a selected test processor subsystem to implement the wideband digital CPMAS algorithm evaluation model shown in Figure 9-2. Extensive in-plant testing using the evaluation model will precede field testing. The field test evaluation model shown in Figure 9-3 is planned to evaluate performance of wideband digital CPMAS in a field environment using actual digital transmission equipments and radio links available during the time frame of the test phase. The test processor subsystem used in in-plant testing will be applied at site A to perform nodal control, station control and CIS functions during field tests. The test processor also simulates transmission system status loading for the WDMS and interfaces with the CPMAS equpiments at site B via its telemetry channel.

The test processor subsystem is shown in Figure 9-4. A Digital Equipment Corporation PDP11/34 processor performs the central processing function using a magnetic core random access memory and a disk memory mass storage device. A printer is provided for test record printout. Two CRT/Keyboard Units represent the nodal control and station control terminal sets for the wideband digital CPMAS tests. Characteristics of the test processor subsystem are summarized in Table 9-1.

During the initial months of the CPMAS option phase, a field test will be conducted to evaluate assessment techniques as a means of assessing digital transmission system performance. The performance assessment techniques to be evaluated are Channel Estimation and Eye Opening Monitoring. Two feasibility models for each assessment technique will be fabricated and used in the preliminary field test evaluation model shown in Figure 9-5. The feasibility models for the selected technique will be later incorporated into the WDMS feasibility models for the CPMAS in-plant and field tests.

The major tasks of the CPMAS option phase are summarized as follows:

1. Design and construct two WDMS feasibility models to facilitate the demonstration of the CPMAS algorithms,

2. Acquire a minicomputer subsystem to be used as the test processor. The test processor will be used to implement and evaluate the Nodal control and station control CPMAS functions and simulate the Communications Interface Set and the digital transmission system model.

3. Design and program selected algorithms for trending and fault isolation and detection. These selected algorithms will be verified during in-plant tests and operational field tests at Ft. Huachuca. The exponential smoothing and direct smoothing trending algorithms will be tested. Signal-to-noise ratio, signal-to-distortion ratio, transmitted signal power, and bit error rate will be trended.

4. Generate programs to simulate digital transmission system status and CIS functions.

5. Generate programs for CPMAS fault and status displays and for CPMAS fault detection/isolation functions.

6. Perform in-plant CPMAS evaluation testing.

7. Perform CPMAS evaluation testing at Ft. Huachuca.

8. Design and construct two feasibility models for each of two assessment techniques (the eye opening monitor will be GFE or its design will be GFI and GTE Sylvania will build to that design),

9. Evaluate assessment techniques during initial months of program in the field test configuration shown in Figure 9-5.

10. Approaches other than trending will be investigated as possible means of increasing the equipment mean time between failures. This will include examining transmission equipment components (e.g., power supplies) and maintenance cycle time.

The test philosophy for the CPMAS option is discussed herein. Candidate CPMAS algorithms for performance assessment, trend analysis, and fault detection/isolation will be tested and compared during the CPMAS Option Phase. The tests will be performed in a controlled environment to insure the usefulness of the test and to guarantee test repeatability. This controlled environment will include inducing equipment failures, injecting interfering signals, and simulating propagation media degradations. Comparative analysis of wideband digital performance assessment techniques can be performed. A simulated microwave system will be used to verify the capabilities of the performance assessment techniques. This is advantageous due to the controlled environment afforded by a propagation media simulator which will allow the testing of the algorithms while the propagation media experiences anomolies not frequently encountered over operational links. However, final verification is desireable on operational links.

The purpose of the performance assessment test program is fourfold: (1) test the performance of the assessment techniques for induced equipment degradations, (2) compare the selected candidate techniques, (3) determine the limitations of the techniques, and (4) assess the techniques as maintenance aids.

The digital transmission equipments necessary for the performance tests are:

a) Two AN/FRC-163 radio sets, or

b) Two DCS standard microwave radios and two T1-4000 multiplexers, or

c) Two DCS standard microwave radios and two Digital Applique Units (DAU), or

TABLE 9-1

CHARACTERISTICS OF
TEST PROCESSOR SUBSYSTEM

CENTRAL PROCESSING UNIT	PDP 11/34
Number of Instructions	400
Processor Word Size	16 bits
Word and Byte Processing	Yes
Direct Memory Access	Yes
RANDOM ACCESS MEMORY	
Magnetic Core Memory	Yes
Capacity	124K Words
Maximum Addressing Capacity	124K Words
Access Time	.510 usec
Cycle Time	1.0 usec
MASS MEMORY	
Magnetic Disk Memory (Fixed Head)	Yes
Capacity	256K Words
Average Access Time	8.5MS
VDU/KEYBOARD UNITS	
Quantity	2
Characters Per Line	80
Lines Per Display	24
PRINTER	
Print Speed	180 Characters/sec
Characters Per Line	132 Characters

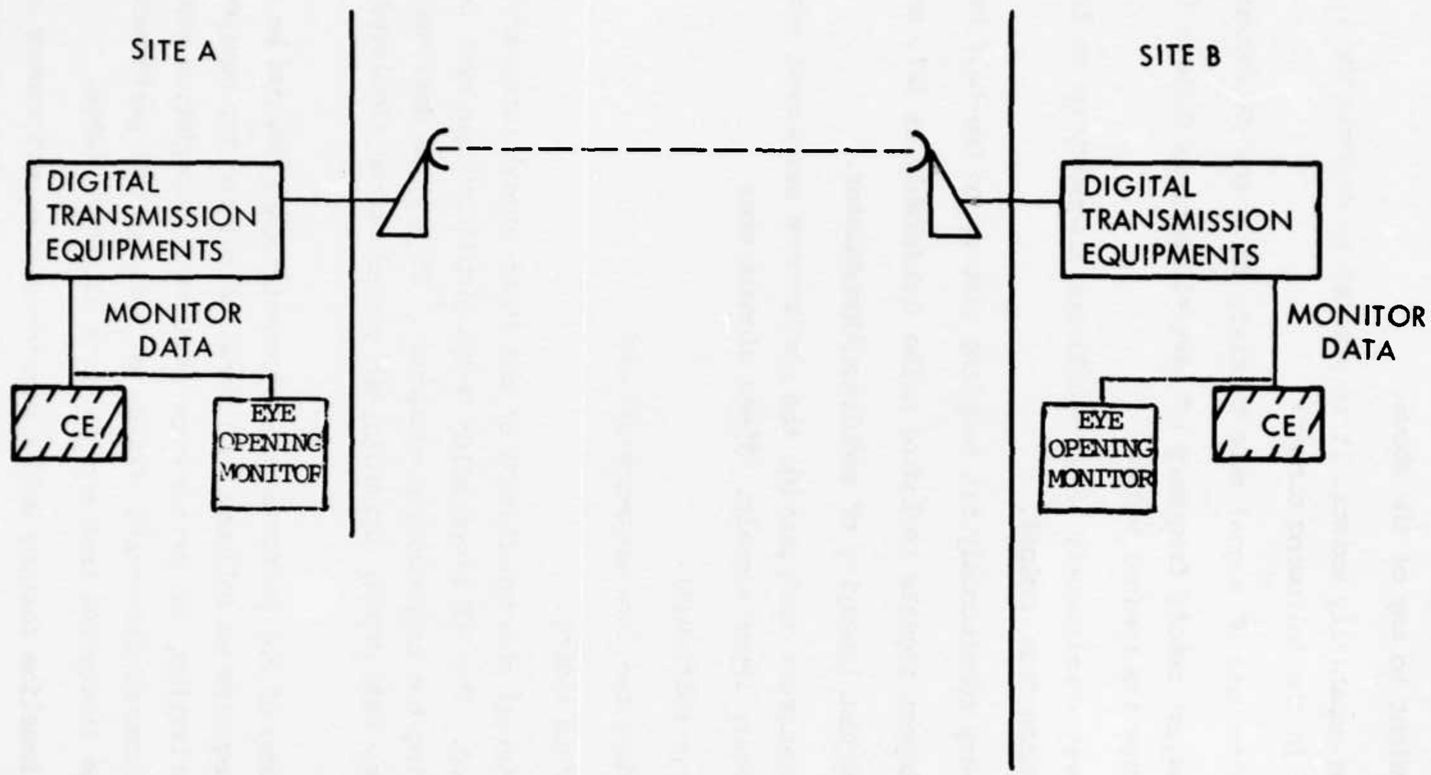

FIGURE 9-5. CE EVALUATION MODEL FOR FIELD TEST

d) Two microwave radios and two digital modems functionally equivalent to any of the above.

If the capability exists, it is planned to degrade the transmission equipment in the following manner:

a) attenuate RF signal zero to sixty dB in one dB increments,

b) adjust cutoff frequency of partial response filters from one-half to twice its nominal value,

c) vary continuously local oscillator frequency up to five percent deviation from nominal,

d) vary continuously bit sampling time up to one-half baud interval,

e) inject signals including noise (preferably at IF), and

f) adjust linearity of modulator/demodulator.

The equipment must provide the performance assessment techniques with the necessary input signals. These signals are:

a) eye pattern(s),

b) detected data sequence(s), and

c) data timing.

The electrical characteristics of the input signal interfaces must be determined. The LOS propagation media simulator used must be capable of interfacing the transmission equipment. It will be desireable to vary the fade rate, fade depth, and multipath spread of the simulated propagation media.

Testing of the performance assessment techniques can be divided into five categories as follows: (1) baseline testing for equipment characterization, (2) performance assessment degradation testing, (3) performance assessment comparison testing, (4) performance assessment technique limitation test and (5) link alignment tests.

The baseline testing will characterize the performance of the transmission system by attenuating the signal and determining RSL versus AGC, RSL versus BER, RSL versus format violation rate, and attenuation

versus BER. The RSL versus AGC data will be obtained by varying the signal attenuation from zero to sixty dB in one dB increments. The other data will be obtained by varying the attenuation from the setting corresponding to a BER of 10^{-10} to sixty dB in one dB increments.

The performance assessment degradation test program would consist of inducing equipment degradations and assessing the performance of the channel estimation and the eye opening monitor. This program would consist of attenuating the RF signal, adjusting the cutoff frequency of the partial response filters, varying the local oscillator frequency, varying the bit sampling time, injecting signals and noise, and adjusting the modulation/demodulation linearity. The degradations will be individually induced such that the BER varies from 10^{-10} to 10^{-2}. For channel estimation, the estimated and measured BER will be used to evaluate the effectiveness of this technique. In addition, BER will be plotted versus SDR for several values of SNR in order to assess the one-to-one correspondence between these parameters. For the eye opening monitor, BER will be plotted versus the eye opening for several values of SNR (independently derived).

The purpose of the comparison testing is to determine whether or not the channel estimation technique provides a significant advantage in assessing performance over other techniques, i.e., eye patterns. The speed of assessment and relative cost of each technique will be noted. The data derived in the degradation induction test program will be analyzed to determine performance assessment accuracy. Early warning (i.e., which technique reacts first and conclusively to a degradation) will be determined by slowly inducing each degradation and noting parameter threshold crossings. These thresholds will be varied to determine degradation detection versus false alarm trade-offs. Data analysis will be performed to determine if either technique can aid in fault isolation. The results of this test program will be used to select the performance assessment algorithm to be included in the WDMS feasibility model.

If a LOS propagation media simulator is available, performance assessment technique limitation determination tests can be conducted to determine when and how the techniques fail to yield useful performance assessment information. These tests would consist of adjusting the multipath spread, doppler

spread, and fade depth until the technique limits are reached.

The link alignment tests will examine the usefulness of the eye opening monitor and the channel estimator as an aid in link alignment. These tests will consist of performing the baseline testing after normal equipment alignment and after the equipment has been aligned to achieve maximum performance as indicated by the performance assessment techniques.

The performance assessment testing would require the following equipment: dual trace oscilloscope, wideband RMS voltmeter, spectrum analyzer, frequency counter, strip chart recorder, PRBS-word generator, and a BER detector.

The effectiveness of trending for failure prediction will be determined. Field testing of trend analysis is required to verify that trending is a viable failure prediction approach. The trending algorithms and trending parameters will be tested for their ability to predict threshold crossings and anticipate equipment alarms. This will be accomplished by slowly inducing equipment degradations, using trend analysis algorithms to predict future parameter values, and from these predictions anticipate equipment alarms signifying equipment failure. Exponential smoothing and direct smoothing are the trend analysis techniques that will be tested. As a minimum, SNR, SDR, TSP and BER will be modeled as a quadratic polynomial, trended and investigated for their ability to predict failures. The equipment degradations that will be induced for the trend analysis testing are the same degradations that will be used for the performance assessment testing. The data will be interpreted to determine the cost of predicting various failure percentages and to estimate the associated lead time to predict failures.

The wideband digital fault isolation concept will be evaluated. Field testing of the fault detection/isolation routine is required to verify the feasibility of the hybrid sequential/signature approach to fault isolation. To test the fault detection/isolation routine, failures will be induced to generate equipment signatures. These signatures will be processed to isolate the induced failure. In addition to the induced degradations as in the trend analysis and performance assessment tests, the fault isolation tests will simulate loss of signal faults.

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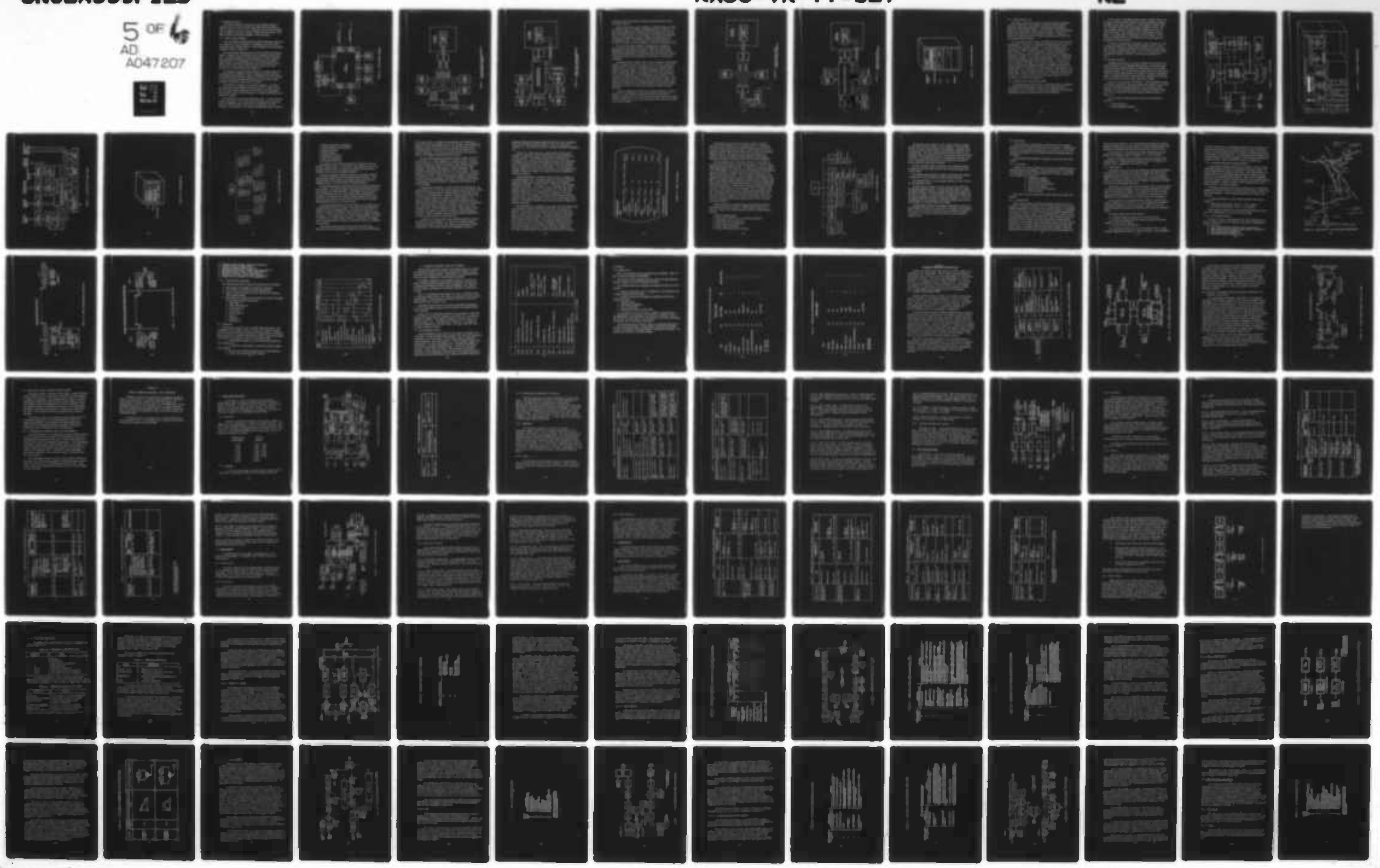

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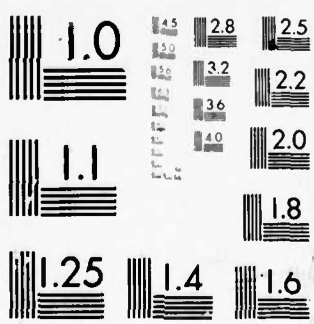

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9.2 Hardware Description

This section presents a description of the hardware required to implement both the in-plant and field test CPMAS evaluation models as shown in Figures 9-2 and 9-3. This includes one test processor subsystem and two Wideband Digital Monitoring Set (WDMS) feasbility models. Each WDMS includes one performance assessment feasibility model.

9.2.1 Test Processor Subsystem

The test processor subsystem provides digital transmission system and CIS simulation as well as a vehicle for implementing the nodal control and station control CPMAS functions. A block diagram of the test processor subsystem is shown in Figure 9-6.

The test processor subsystem consists of two functional and physical modules. These are the test processor and the simulator interface hardware. The primary element of the test processor is a Digital Equipment Corporation PDP 11/34 miniprocessor with 128 K words of core memory. Other elements of the test processor are a 256 K word fixed-head disk, a 180 CPS, 132 CPL line printer, and two keyboard display units (KDU) with 80 CPL, 24 lines per page screen capability.

The simulator interface hardware provides the interface between the test processor and the WDMS for digital transmission system simulation. The interface hardware provides inputs to the WDMS from the test processor to simulate digital transmission system monitor points, digital radio basebands (eye patterns), and mission bit streams.

This hardware is composed of two functional modules. The first is the transmission system simulator interface as shown in Figures 9-7 and 9-8. The three primary components of this interface are a programmable DMA controller (part of the test processor), 4 K bytes of RAM memory, and a hardwired controller.

The organization of the memory effectively forms a 2 K byte dual port random access memory. This is done so that the memory space can be both read by the WDMS and written into by the test processor via the DMA controller, simultaneously. This prevents the WDMS from having to wait for

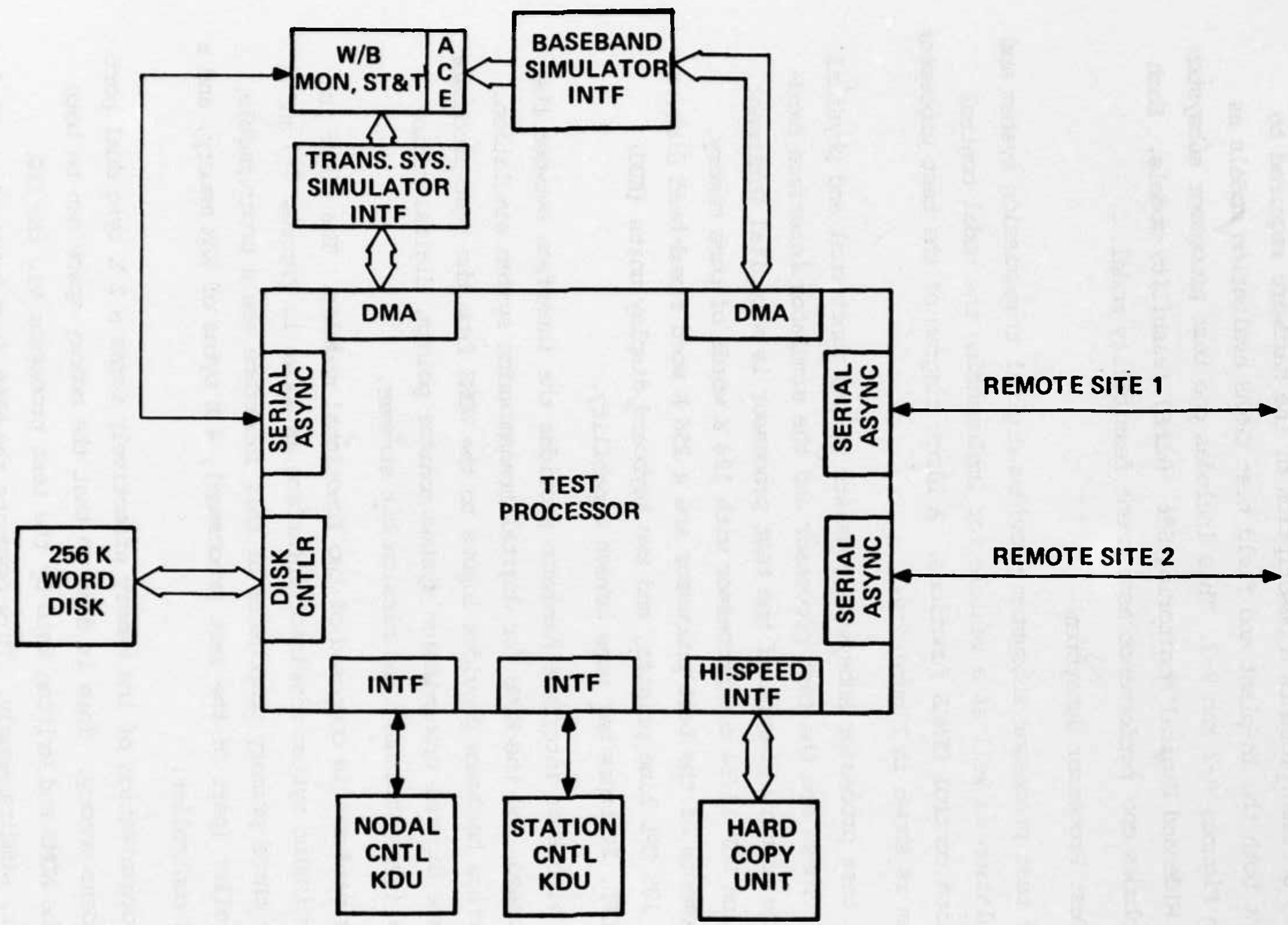


FIGURE 9-6. TEST PROCESSOR SUBSYSTEM

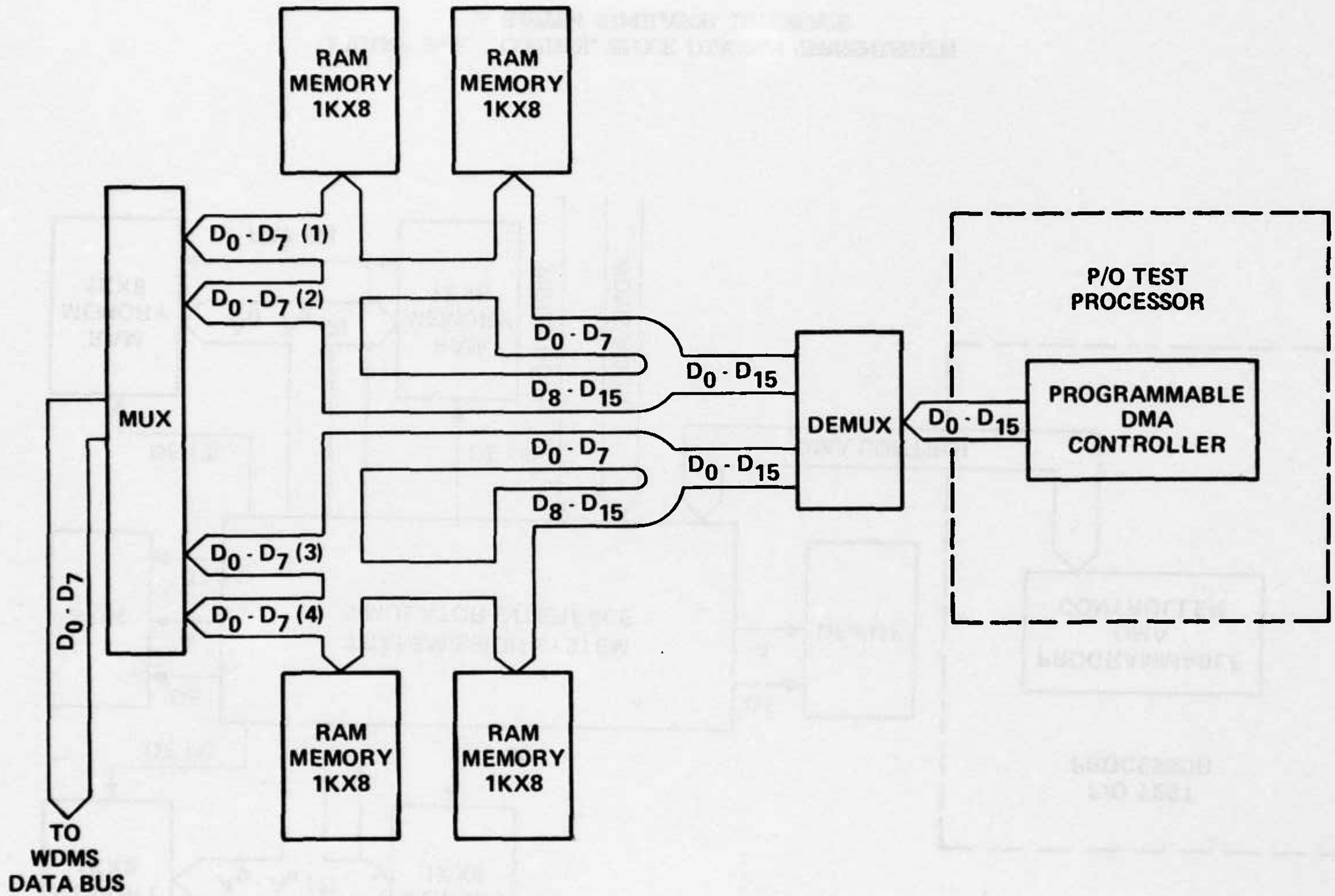


FIGURE 9-7. DATA PATH BLOCK DIAGRAM TRANSMISSION SYSTEM SIMULATOR INTERFACE

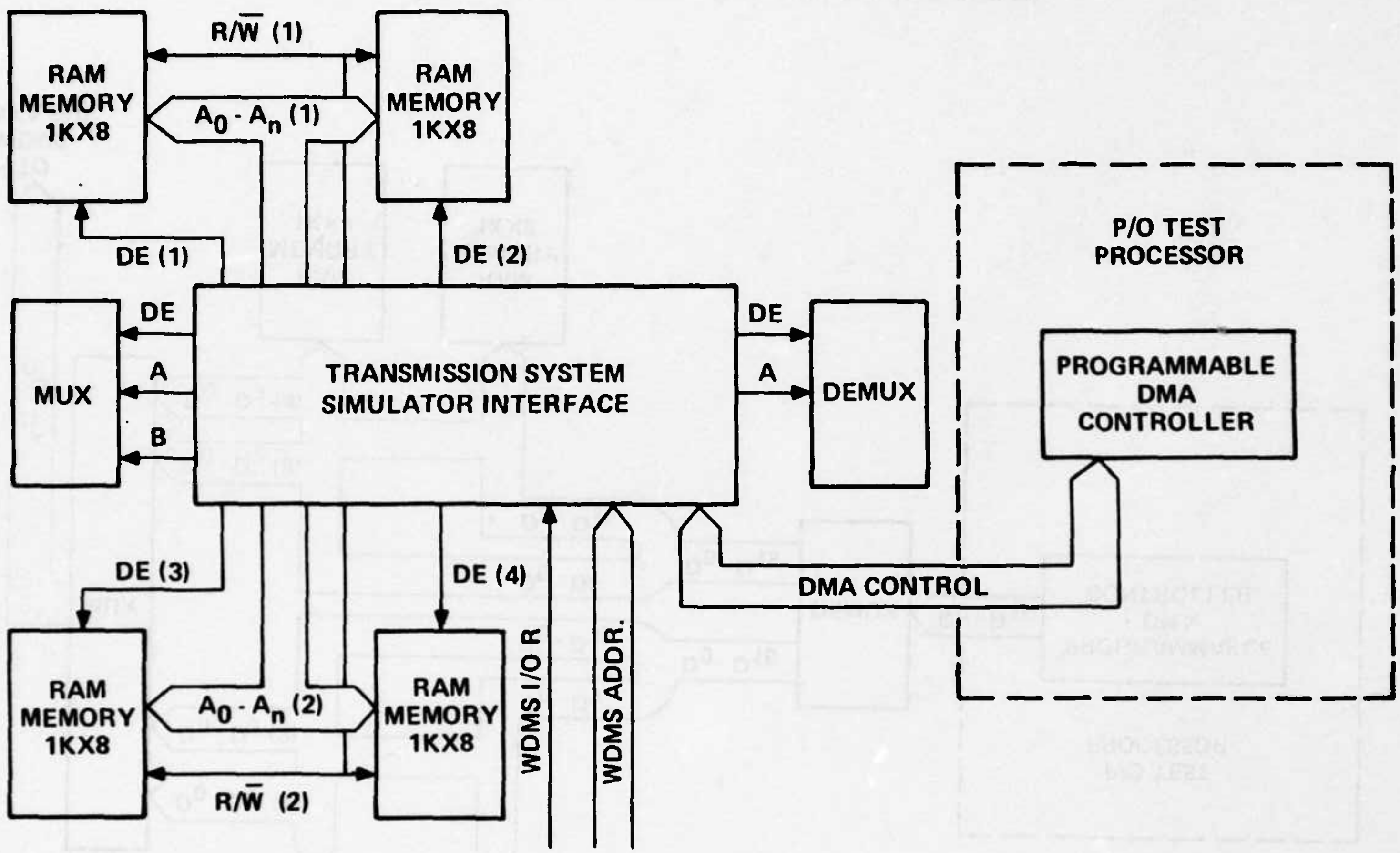


FIGURE 9-8. CONTROL BLOCK DIAGRAM TRANSMISSION SYSTEM SIMULATOR INTERFACE

monitor point data, and allows the simulator to duplicate more closely real world conditions.

Routing of data from the test processor to interface memory, and from the interface memory to the WDMS, is accomplished by the controller. By monitoring the WDMS bus and I/O READ line, and by keeping track of which half of the memory space is in the read mode, the controller provides the contents of the apprpriate location in memory to the WDMS data bus at the appropriate time. At the same time, the controller controls the writing of new data by the test processor into the write mode memory space.

The size of the required memory is determined by the number of monitor points which exist at an eight (8) DRAMA radio station model, considered to be the maximum size station. This size station contains 4512 binary monitor points, 312 frame error pulse monitor points, and 448 analog monitor points, which translates to 1324 bytes of monitor point information.

The second functional module of the interface hardware is the baseband simulator interface, as shown in Figures 9-9 and 9-10. This hardware is almost identical in function and composition to the transmission system simulator interface hardware. The primary difference is that both the input and output data ports of the memory are 16 bits wide, as opposed to 16 and 8 bits respectively for the transmission system interface. Also, the effective size of the memory is 3 K words rather than 2 K bytes. This results from the fact that the channel estimation algorithm requires 3000 samples for convergence, and each sample consists of an eye pattern sample (quantized to 8 bits) and a sample of 8 consecutive mission bit stream data bits.

A physical representation of the test processor subsystem is shown in Figure 9-11. The subsystem includes three 10½-inch high drawers of processor equipment, an 8 3/4-inch high card nest containing three interface hardware wirewrap cards, and a 3½-inch high power supply module which powers the interface hardware.

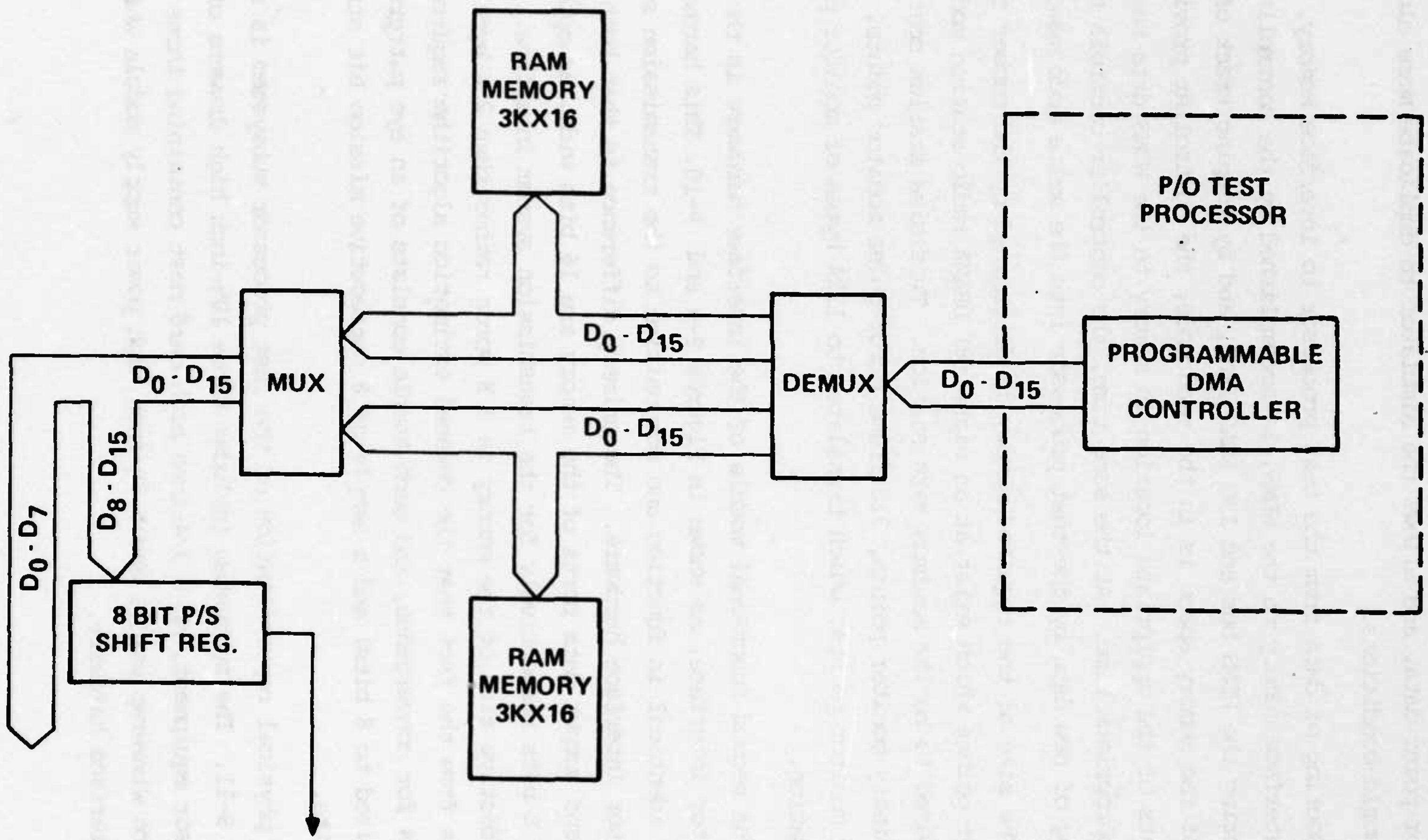


FIGURE 9-9. DATA PATH BLOCK DIAGRAM
BASEBAND SIMULATOR INTERFACE

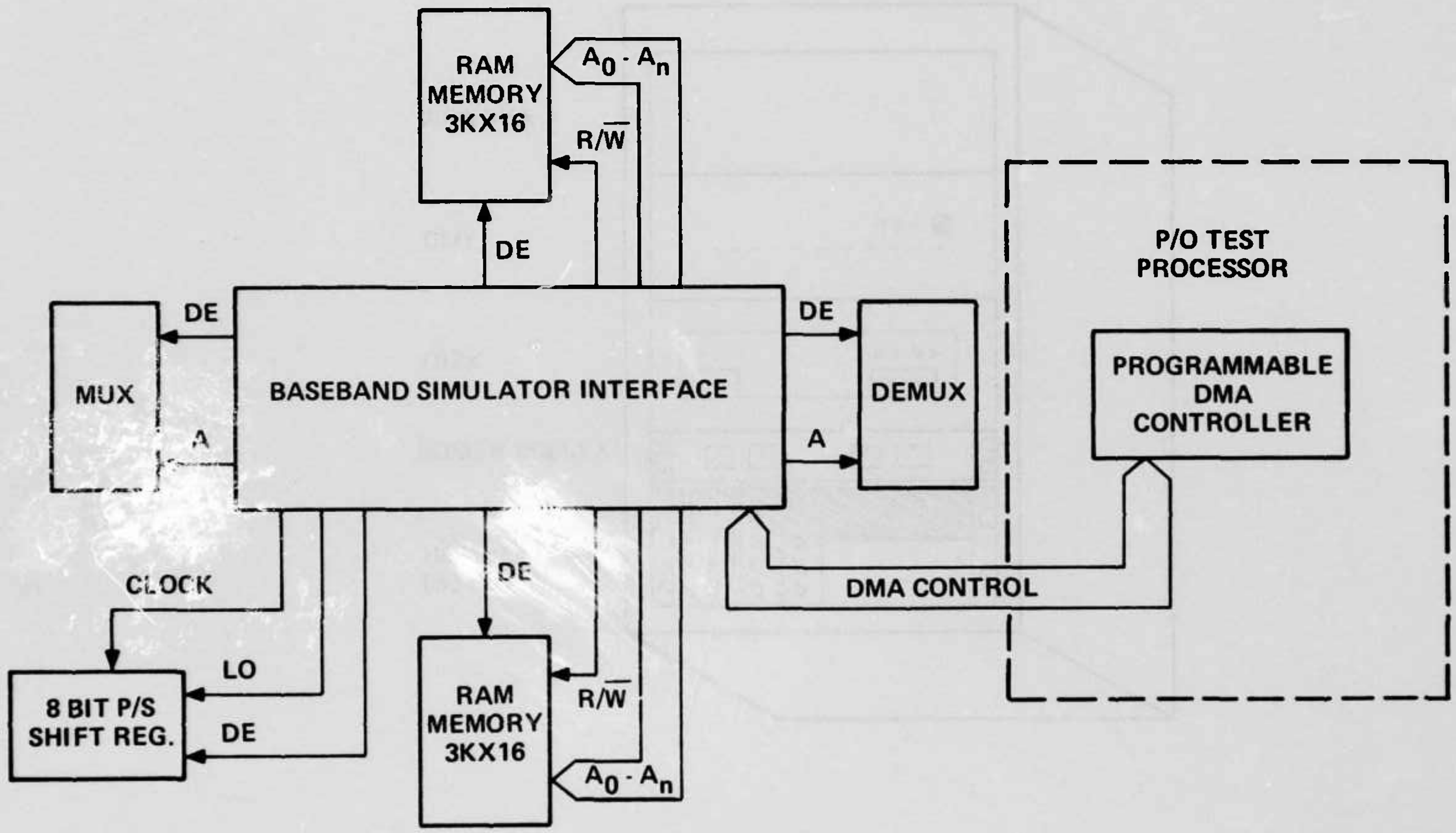


FIGURE 9-10. CONTROL BLOCK DIAGRAM BASEBAND SIMULATOR INTERFACE

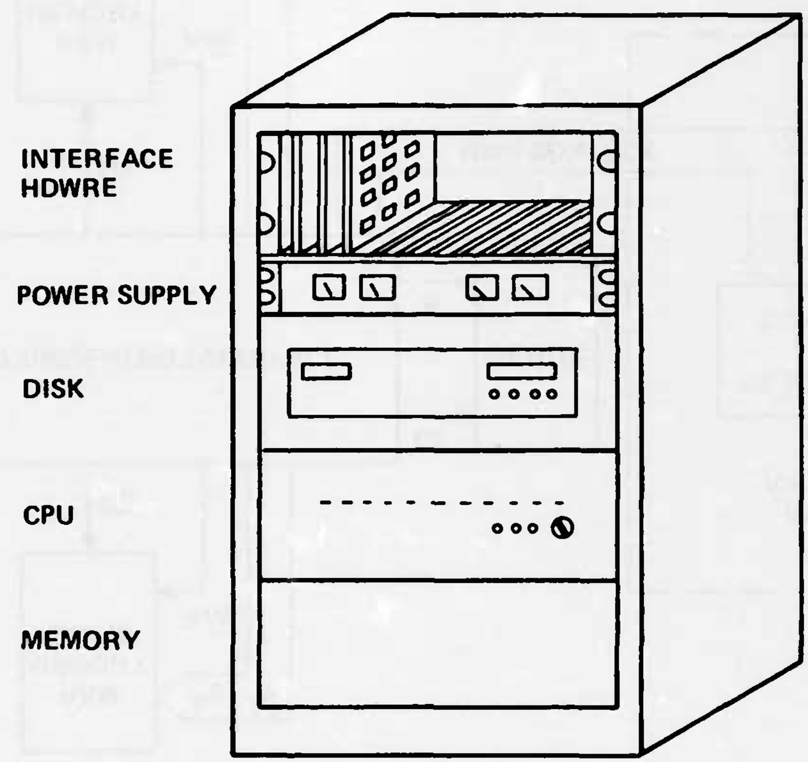


FIGURE 9-11. TEST PROCESSOR SUBSYSTEM

9.2.2 Channel Estimator (CE)

The hardware required to implement the channel estimation assessment technique is primarily a microprocessor requiring microcoded program memory and random access data memory. The microprocessor computes tap weights for a channel model using an iterative process. The micro-processor applies other algorithms to the calculated tap weights to compute bit error rate, signal-to-noise ratio, signal-to-distortion ratio, and linear-to-non-linear-distortion ratio.

The CE feasibility model assumes two configurations for the feasibility demonstrations. The first is a stand-alone configuration which is used for the CE field test as shown in Figure 9-5. The block diagram for this configuration is shown in Figure 9-12, and a pictorial representation is shown in Figure 9-13. In this configuration, the CE is controlled by front panel switches, and the results of its calculations are displayed on alphanumeric readouts. In the second configuration, the CE is incorporated as part of the Wideband Digital Monitoring Set (WDMS). In this case, the CE is controlled by the WDMS, and its outputs are eight bit binary words which are supplied to the WDMS upon request. The WDMS also performs the baseband sample, A/D conversions, and the mission bit stream sample for the CE processor. Thus, the sample card logic, the control panel switches, the display LEDS, the shift register, and the 128 x 16 PROM look-up table shown in Figure 9-12, as well as the control panel shown in Figure 9-13, are not required in the second configuration.

9.2.3 Wideband Digital Monitoring Set (WDMS)

The Wideband Digital Monitoring Set is designed primarily to implement the wideband digital measurement function for the CPMAS feasibility demonstration. This is defined as station level performance monitoring and assessment of frame error rates and digital radio basebands.

A block diagram of the WDMS feasibility model is shown in Figure 9-14. The model is sized to provide enough data acquisition hardware to monitor the DRAMA stations shown in Figure 9-3. This includes the signal conversion, multiplex, pulse counter and parameter conversion circuits. The common hardware, however, is sized to handle a maximum size eight (8) radio nodal station. This includes the CPU, program memory, and data memory. The large station is simulated by the test processor. The CE processor baseband inputs are also simulated by the test processor for the purpose of in-plant testing.

A pictorial representation of the WDMS is shown in Figure 9-15. The configuration consists of 7 wirewrap cards contained in one 8 3/4-inch high card nest, 6 wirewrap cards contained in one 5¼-inch high card nest, and a 5¼-inch high power supply module. The 8 3/4-inch high nest contains the WDMS logic exclusive of the CE. The other nest contains the CE logic.

9.3 Software Description

The CPMAS option phase will be used to demonstrate the feasibility of selected portions of the recommended CPMAS approach. The software system includes the test processor software, the WDMS software, and the channel estimation software. The test processor software emulates the nodal control and station control CPMAS functions and simulates the digital transmission system. The WDMS and channel estimation software, accepts real-time inputs from test generation facilities and/or operational equipment.

As part of the feasibility demonstration, the test processor software will control the testing of operational CPMAS system elements as well as the testing of the CPMAS algorithms selected for use at the nodal control subsystem (i.e., fault detection/isolation, trending, performance assessment, etc.) A family tree of the test processor software is given in Figure 8-16.

The test processor software system contains the following major functions.

1) Executive Control
2) Status Assessment Processing

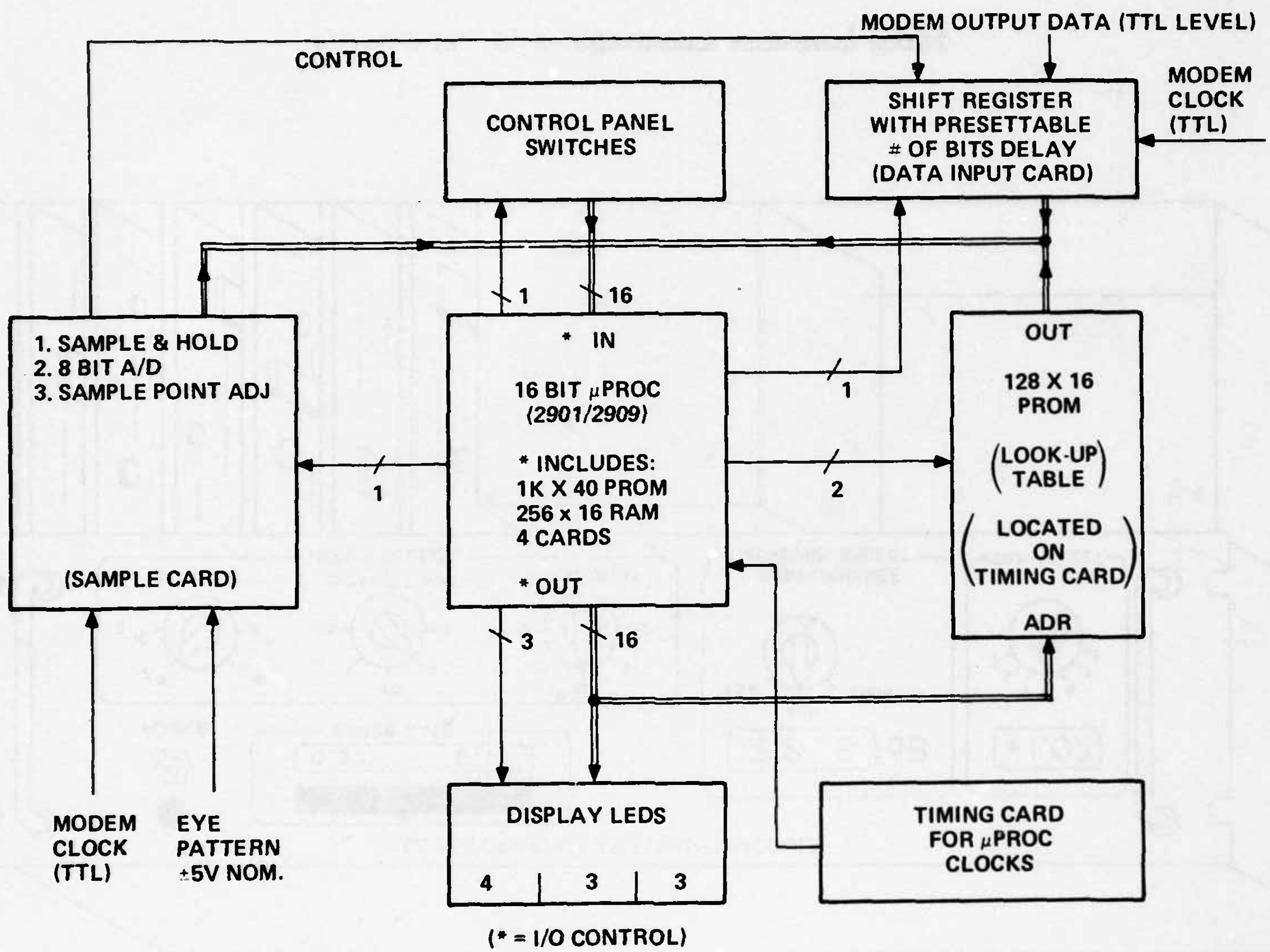


FIGURE 9-12. C. E. BLOCK DIAGRAM

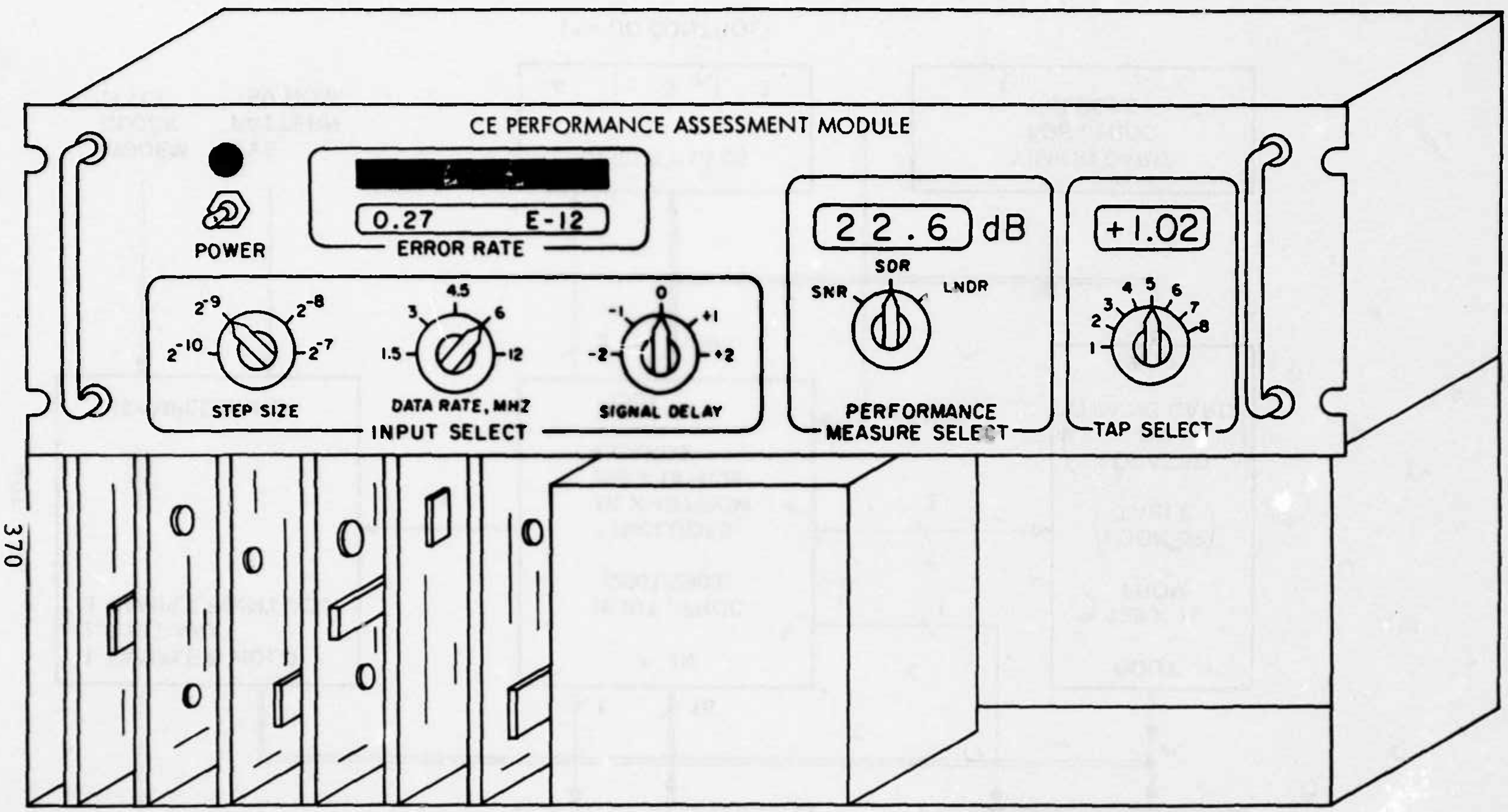


FIGURE 9-13. C. E. PERFORMANCE ASSESSMENT MODULE

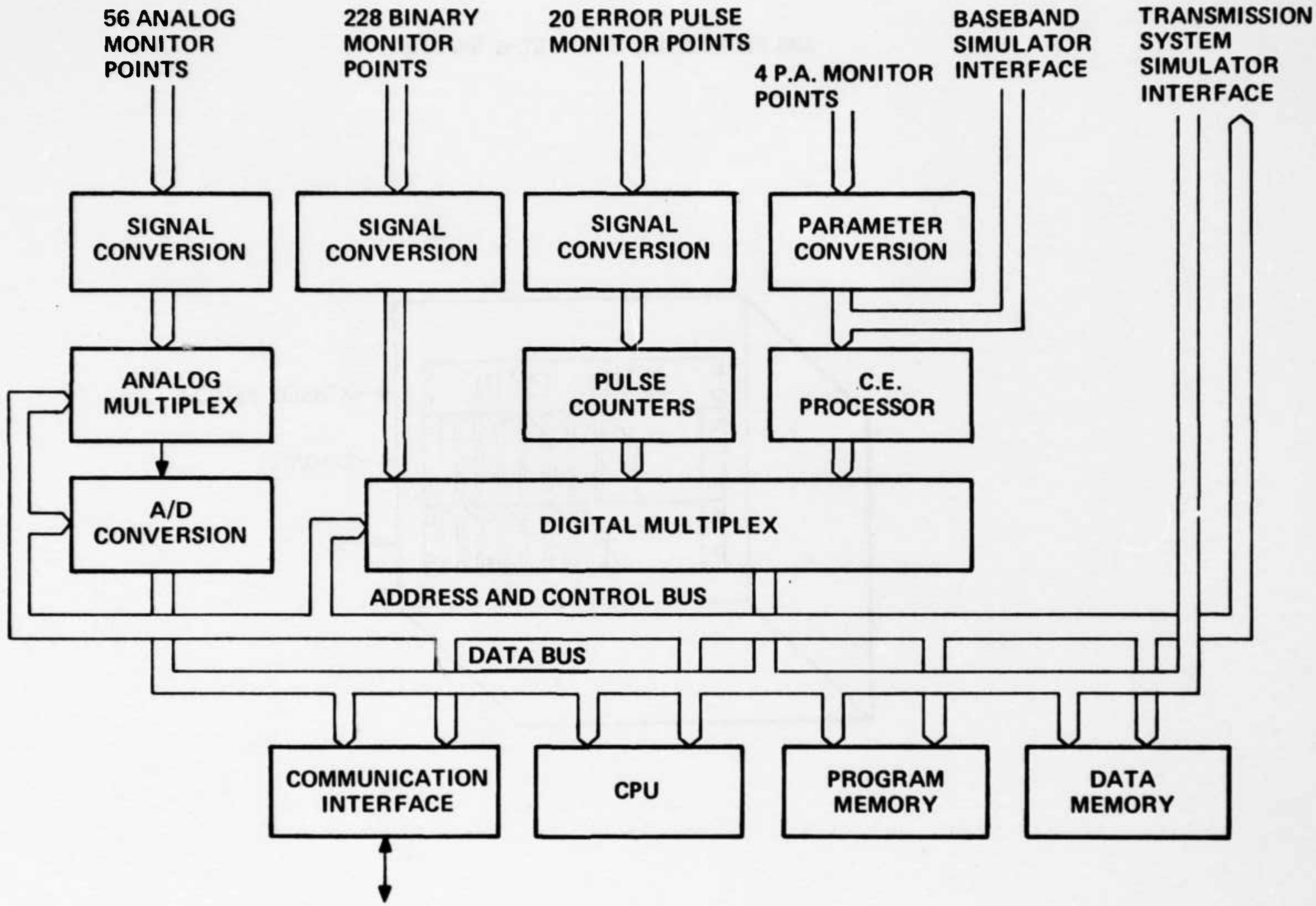


FIGURE 9-14. W/B MONITORING SET BLOCK DIAGRAM

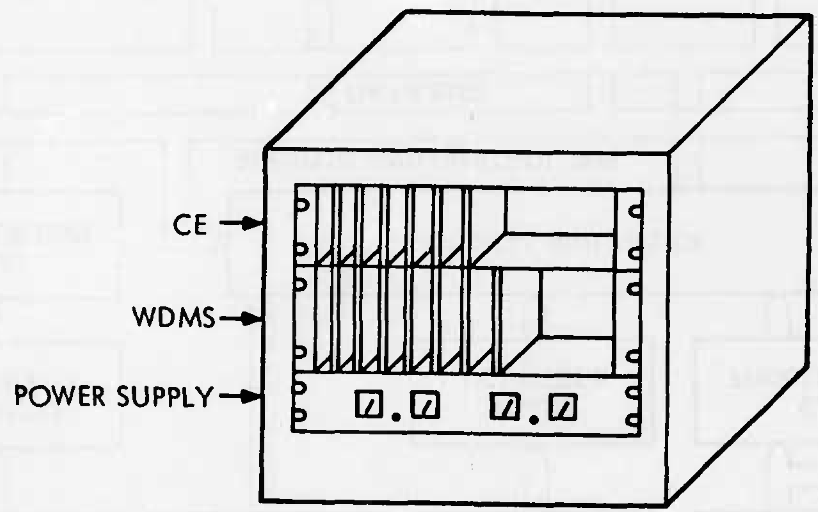


FIGURE 9-15. W/B MONITORING SET

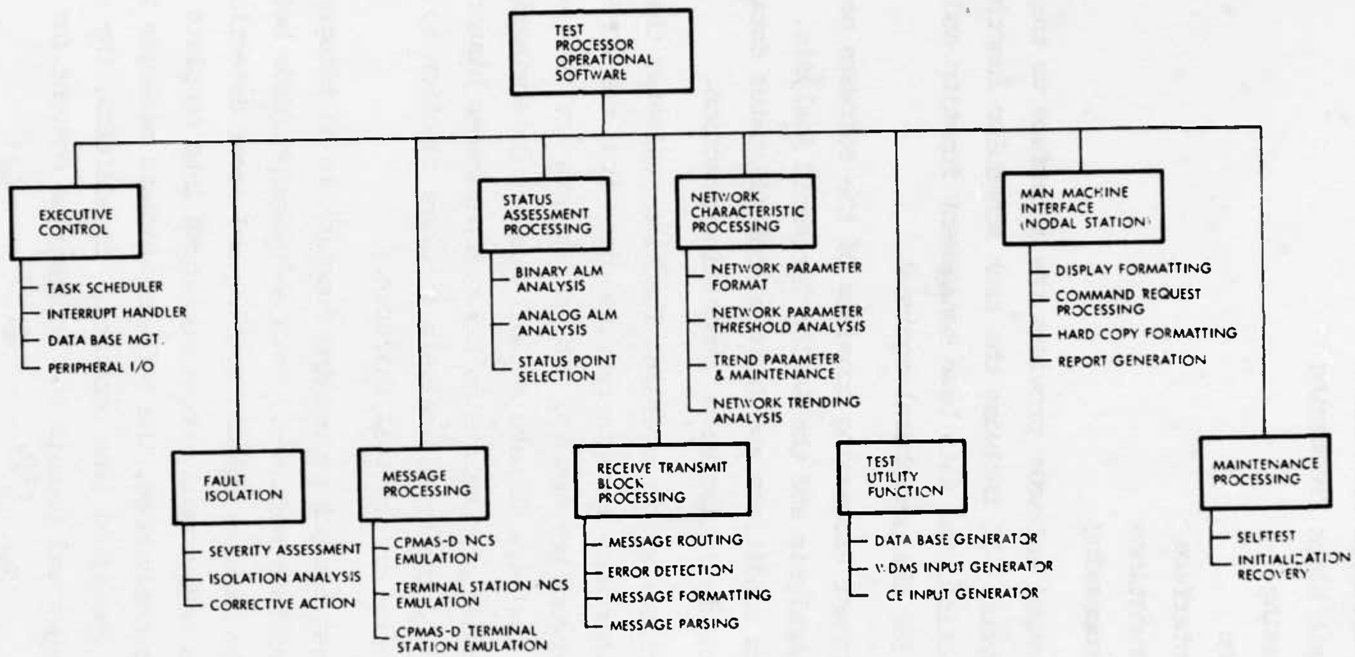


FIGURE 9-16: TEST PROCESSOR FAMILY TREE

3) Network Characteristic Processing
4) Receive/Transmit Block Processing
5) Message Processing
6) Fault Isolation
7) Man/Machine Interface
8) Test Utility Functions
9) Maintenance Processing

The executive control software provides the interface to the test processor operating syste. It includes the task scheduler function, the interrupt handler function, the data base management function and the formatting functions for the peripheral equiment.

The Status Assessment Processing consists of the software necessary for the Binary Alarm Analysis and the Analog Threshold Analysis. This software detects alarm conditions and formats control/status data for subsequent input to the fault isolation processing function.

The Network Characteristic processing function evaluates the condition of the network. The software accepts received data from the WDMS function and calculates the network parameters. The parameters are then used as a basis for subsequent analysis to make network quality determinations. In addition, the software also maintains network parameter history data. This data is analyzed by the trend analysis software function to detect system degradations prior to critical failures.

The receive/transmit block processing function is an integral part of the communication interface software. This software performs header/tail analysis to facilitate message (block) routing and error detection. In addition it assembles individually received blocks into complete messages. Similarily, in the transmit mode, the software formats messages into blocks as necessary for the specified line protocol. In addition, the software parses received messages and formats the information content for subsequent data processing.

The message processing software accepts data from the receive processing function and implements the appropriate functions as determined

by the received data. An example of such processing is the handling of status and monitor data messages received from the WDMS. These messages are received, analyzed, and acted upon by both the NCS and station control. In the NCS they serve as the basis for the fault detection/isolation and trending processing. At the station controller position they provide the basis for the equipment status monitoring and control.

The fault detection/isolation software provides a mapping of sets of alarm signals (i.e., failure symptoms) to a particular fault. The fault isolation software is driven by the received status assessment processing. Following a preliminary analysis of the binary alruns and the analog thresholds, the abnormal data undergoes a severity assessment. The assessment software prioritizes the faults in a working queue. Isolation software then performs analysis gated by the fault priorities to determine the equipment at fault. Once the malfunctional equipment is identified, operator notification processing is initiated. Corrective action displays are generated to assist the operator in identifying and rectifying the faulted equipment.

The man/machine interface is a vital portion of the CPMAS system. The keyboard display unit at the nodal control position and/or the station control position is the primary physical interface between the Nodal/Station Tech Controller and the CPMAS system. Software to emulate both display generation and command processing is resident in the test processor. The technical control displays and display organization developed during the CPMAS study phase will be evaluated. The types of displays at the nodal control include Fault Summary Display, Fault Detail Display, Fault Detail Equipment Display, and Path Description Display. These displays, as well as others, are generated to evaluate the technical control man-machine interface. Likewise, equipment status and control displays generated for the station control position are also evaluated.

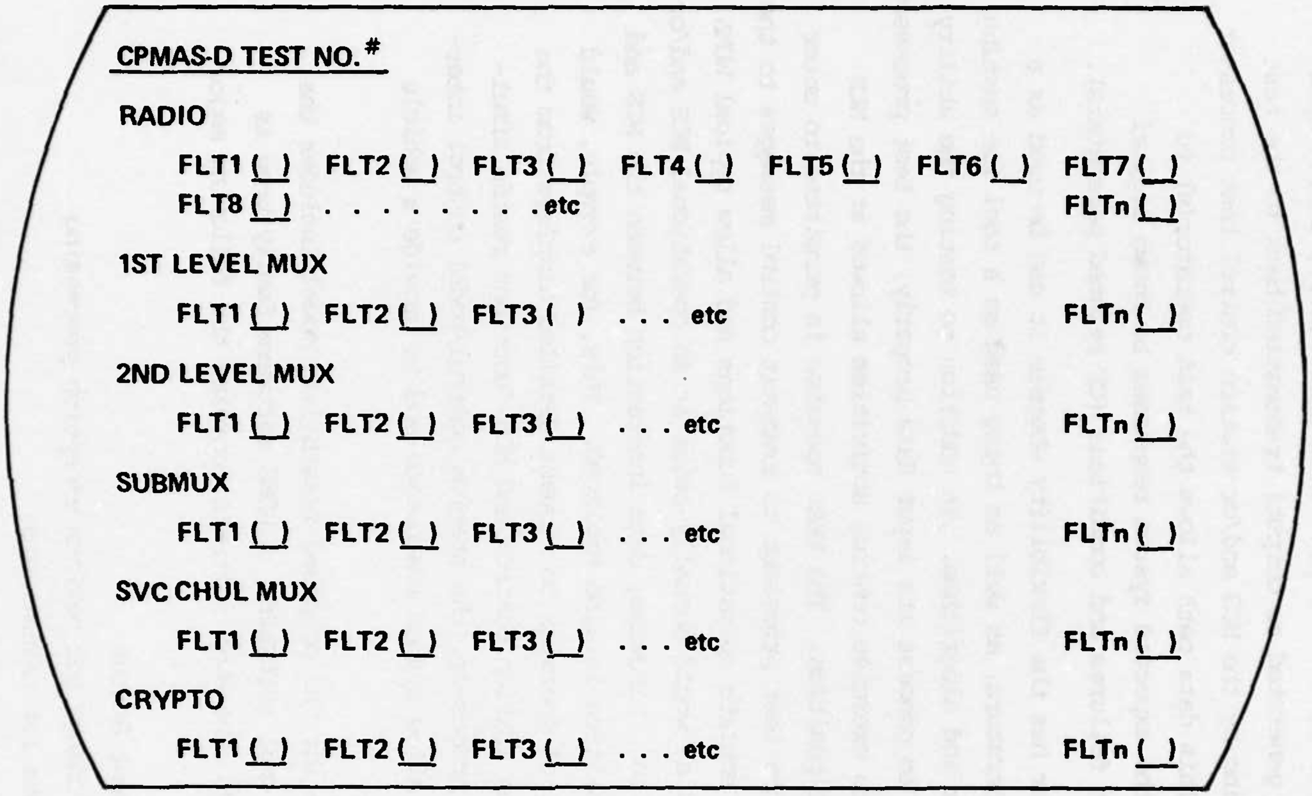
In addition to emulating nodal control subsystem functions, the test processor will contain software, i.e., test utility function software, designed specifically to control test scenarios in the feasibility model configuration. This software controls the comprehensive testing of

operational CPMAS system elements (WDMS including CE) as well as extensive testing of the CPMAS algorithms selected for use at the nodal control subsystem (i.e., fault detection/isolation, trending, performance assessment, etc.).

Testing of the CPMAS operational elements (WDMS including the CE processor) is supported by special data generation software residing in the test processor. This software accepts inputs initiated by the NCS operator at the terminal, generates data for input to the CE processor and/or Alarm Monitoring portion of the WDMS, and stores this generated data in the appropriate test input buffer area(s). This test processor resident software will provide the test operator(s) with the capability to generate a desired test scenario, the results of which are observable at the display terminals.

A typical WDMS scenario includes the operator entry of commands via the keyboard display unit. The operator types in the scenario generated command for CPMAS-D and the system software responds by displaying a predefined entry format. (See Figure 9-17). The operator then indicates the item to be faulted. In the case of binary alarm faults the operator requests a change in the state of a particular alarm. For those items requiring a data value (i.e., analog levels) the operator will type in the actual value to be included. In each case when the operator does not command a change a predefined default value is used by the software during the test. This method of implementation allows the operator flexibility in generating test data.

This implementation is expandable to the extent that the software stores fixed scenarios of commonly used data sets which are initiated by the operator. This capability will increase the efficiency by reducing the amount of operator input required. The software provides the additional capability of allowing the operator to create the fixed scenario data sets to support desired testing. In this case the operator enters the stored scenario he wishes to change. The operator may change as many of the fields as desired. Once the update is complete, the operator can either save the updated scenario or invoke the scenario command which will save the updated scenario and initiate the execution of the scenario.



= NEW LINE CHARACTER

UNDERLINED AREA IS TYPED BY THE OPERATOR WHEN CHANGE IS DESIRED

FIGURE 9-17. CPMAS-D TEST DISPLAY

The generated test data will be monitored (input) by the WDMS operational system element, and the processed input (i.e., status data reported by exception generated as output) transmitted back to the test processor for processing by the NCS and/or station control test processor emulation software. This data path allows the test operator(s) to observe in real-time the expected system responses to known Digital Transmission Equipment failures and conditions (CE related parameters).

The test processor has the flexibility wherein it can be used as a training device for operators, as well as being used as a tool for testing CPMAS system equipment and alogrithms. In addition to testing the ability of the WDMS equipment to process its input data properly, the test processor permits the operator to exercise control activities allowed at the NCS and/or station control position. The test operator is permitted to enter commands which cause the test processor to transmit control messages to the WDMS. These messages emulate operational functions and allow typical WDMS monitoring and control as would normally exist at an operational NCS and/or station control position. Likewise, data interaction between the NCS and the station control position is also emulated. This, for example, would allow the station control operator to request detailed displays from the NCS. Although both the station control and NCS functions reside simultaniously in the test processor, the station control/nodal control interaction is emulated to allow system evaluation and to provide a vehicle for operator training.

The WDMS software for the proposed feasibility model includes the full extent of operational software. A WDMS software family tree is defined by Figure 9-18. The WDMS software contains the following major functions.

1) Monitor Equipment Status
2) Detect status change and perform exception processing
3) Format WDMS data for transmission
4) Input/output protocol processors
5) Perform command processing
6) Perform CPMAS WDMS selftest functions.

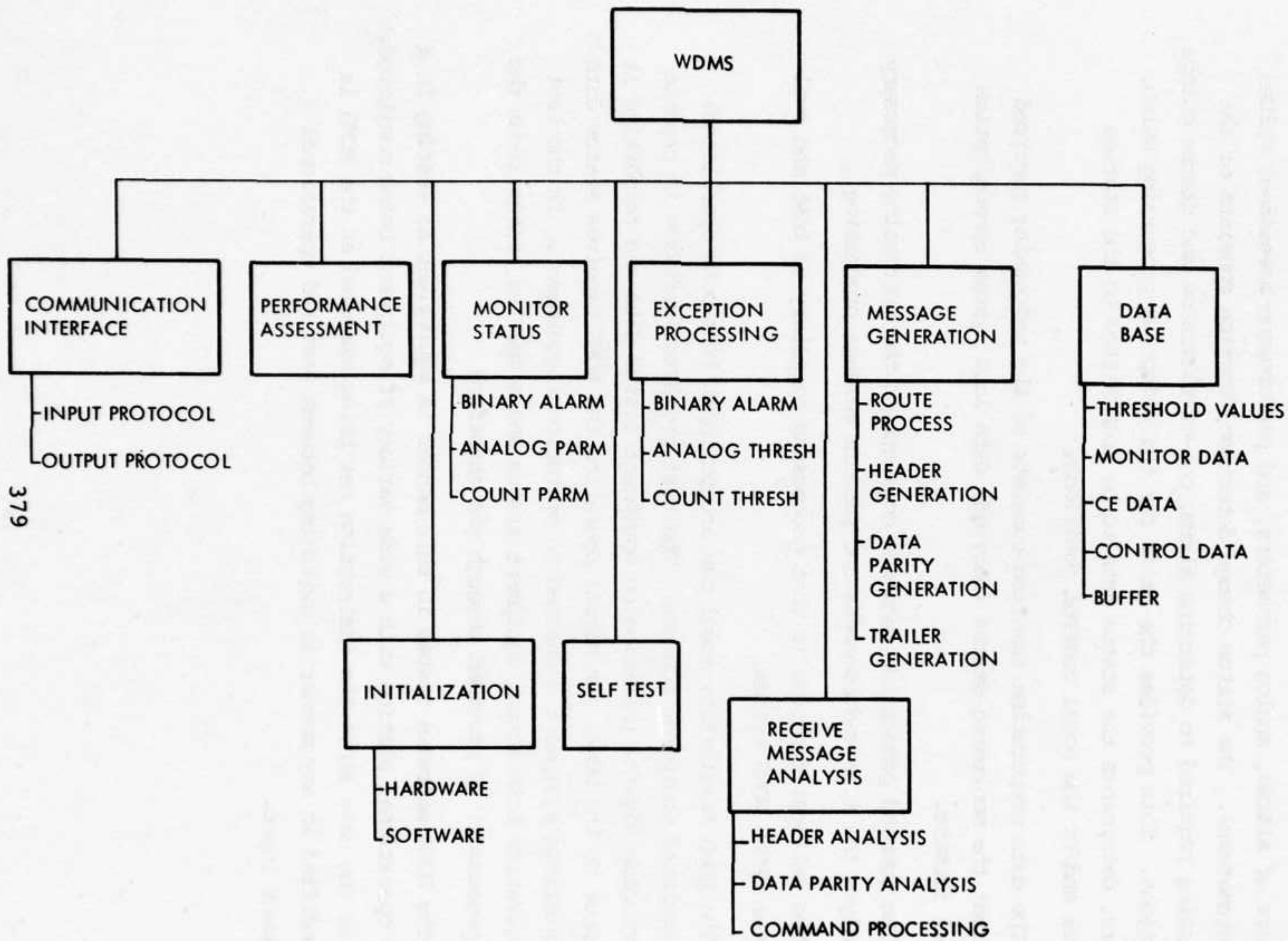


FIGURE 9-18. WDMS FAMILY TREE

The equipment monitor function is the software required to monitor and store the status of individual station equipments. The status data consists of alarms, analog parameters, and performance assessment values (CE parameters). The status change detection function consists of the processing required to determine alarm, out-of-tolerance and status change conditions. This provides the basis for the exception processing which, in turn, determines the status data to be transmitted to the station control and/or the nodal control positions.

The data preparation function consists of the processing required to format the monitored status (derived) data into system communication channel formats.

The command processing function consists of the processing necessary to analyze the received commands and perform message processing.

The selftest function is that processing necessary to test and evaluate the CPMAS WDMS system.

The WDMS feasibility model can accept input from both operational and simulated equipment sources. The test processor software is capable of producing digital transmission equipment status data and formatting it for input to the WDMS. In normal operation the WDMS receives status data via interface equipment connected to operational equipment. In the test configuration both actual equipment status and simulated status (from the test processor) is provided through the interface.

The WDMS software tested in this manner is equivalent to testing in a fully operational station with a wide variety of equipment being monitored. This is the case since the instruction set being executed at the WDMS is not modified in any manner in switching between test and operational equipment input.

9.4 Test Program

The test program to demonstrate the feasibility of the recommended options consists of in-house and CONUS tests (Ft. Huachuca). A comprehensive test plan is to be formally submitted prior to the start of this test cycle. The plans and procedures will be developed during the development phase of the program.

The following sections present a discussion of each facet of the Test Program.

9.4.1 Site Surveys

Personnel will visit the CONUS test site during the development phase to determine interface requirements. A site survey data book will be prepared for this purpose in order to expedite gathering of site data. Typical data to be included is the following:

a. Transmission equipment
b. Existing power capability
c. Station grounding requirements
d. On-site test equipment
e. Administrative area availability
f. Floor plan layout

The results of the site surveys will provide inputs to the overall test planning.

9.4.2 In-House Tests

Formal in-house tests will commence immediately following test and integration of hardware and software. Prior to formal testing, all test plans/ procedures submitted to the government will have been approved. The proposed in-house test schedule is one month at GTE Sylvania, Needham, Massachusetts. The preliminary in-plant testing of the hardware/software, resulting from the study-development phases of this program, will require simulated signals and conditions normally obtained from the monitored digital system equipment. Specifically, input signals (binary states/alarms, digital and analog signals, telemetry data bit streams) capable of being varied over the design ranges must be input to the system to exercise the hardware (sensors, converters, displays) and the software modules associated with providing assessment and

trending and fault detection. The reporting/display subsystem that includes operator interfaces will be used to obtain test results (displays/alarms) that demonstrate program/data base loading and operator query/control actions.

For these tests it is anticipated that normal telecommunications and general test equipments listed in Paragraph 9.4.3.2 will be required.

Results of testing are to be thoroughly analyzed with respect to performance results. Hardware/software alterations will be incorporated, as required, prior to deployment to the CONUS test bed.

9.4.3 CONUS Testing

Formal CONUS testing will take place immediately following the conclusion of in-house tests. Two weeks are planned for shipping and installing the equipment and interfacing with the test bed at CONUS. The test program at CONUS is planned for six weeks on an eight-hour day, five-day week schedule. Testing of the Channel Estimator, part of the WDMS, is scheduled at the CONUS site early in the development phase also.

The contractor test personnel who participated in the in-house test phase will conduct the CONUS test phase. They will receive management and in-house support from GTE Sylvania, Needham. It is assumed that military and other contractor personnel assigned to the test bed will be responsibile for the maintenance of the communications test bed other than the GTE equipment.

On-site personnel will require DOD Secret clearance. Special cryptographic clearances will be required to the level determined by the specific cryptographic equipment in use at the test bed. Special test bed site access clearance will berequired as determined by the site facility Security Branch.

Preliminary objectives of these tests are:

a. To evaluate CPMAS performance on a live microwave link.

b. To perform assessment and fault isolation by use of pre-faulted conditions to the extent allowable.

c. To obtain trend prediction data.

It is understood that the test bed may be located at the U. S. Army Strategic Communications Command, Ft. Huachuca, Arizona. Our understanding

is that at that facility, the transmission equipment can be configured in a back-to-back configuration, with transmitting and receiving facilities co-located, utilizing a repeater station to simulate an unmanned relay station and providing a two-way media path. It is understood that GTE Sylvania will be granted access to the various equipments in this microwave communications transmission chain. Figure 9-19 shows the local Ft. Huachuca area.

9.4.3.1 Microwave Communication Equipment Required

An operational microwave system which may be used to verify the recommended CPMAS approach is shown in the attached block diagram (Figure 9-20 entitled CPMAS Evaluation Model for Field Test). This system consists of a manned terminal and an unattended repeater station with monitoring alarm functions at the unattended repeater station. These would be telemetered back to the terminal station for further processing by the automated technical control equipments. Figure 9-21 shows a similar configuration for early program testing of the Channel Estimator.

The equipment planned for CONUS testing should consist of transmission equipments configured to operate in a diversity mode in order to verify the total CPMAS capability. Such an operational system would consist of the following:

a. Radio Set AN/FRC-163, or DCS Standard Microwave Radio with DAU, quantity 4.

b. Multiplexer/Demultiplexer, TD-1192 ( ) (P)/F, quantity 1

c. Multiplexer/Demultiplexer, TD-1193 ( )/F, quantity 1

Other equipment, materials, and various services required at the test site will be determined as part of the site survey tasks.

9.4.3.2 Test Equipment Required

Following is a list of test equipment which is anticipated to be required to support testing at the CONUS site (the number of parentheses indicate the quantity):

a. Dual trace oscilloscope, HP-Model 1707B or equivalent (1)
b. Wideband RMS reading voltmeter, HP Model 3400 A or equivalent (1)
c. VTVM, HP Model 410C or equivalent (1)
d. VOM, Simpson 260 or equivalent (1)
e. UHF-Signal Generator, HP-Model 620B (1)

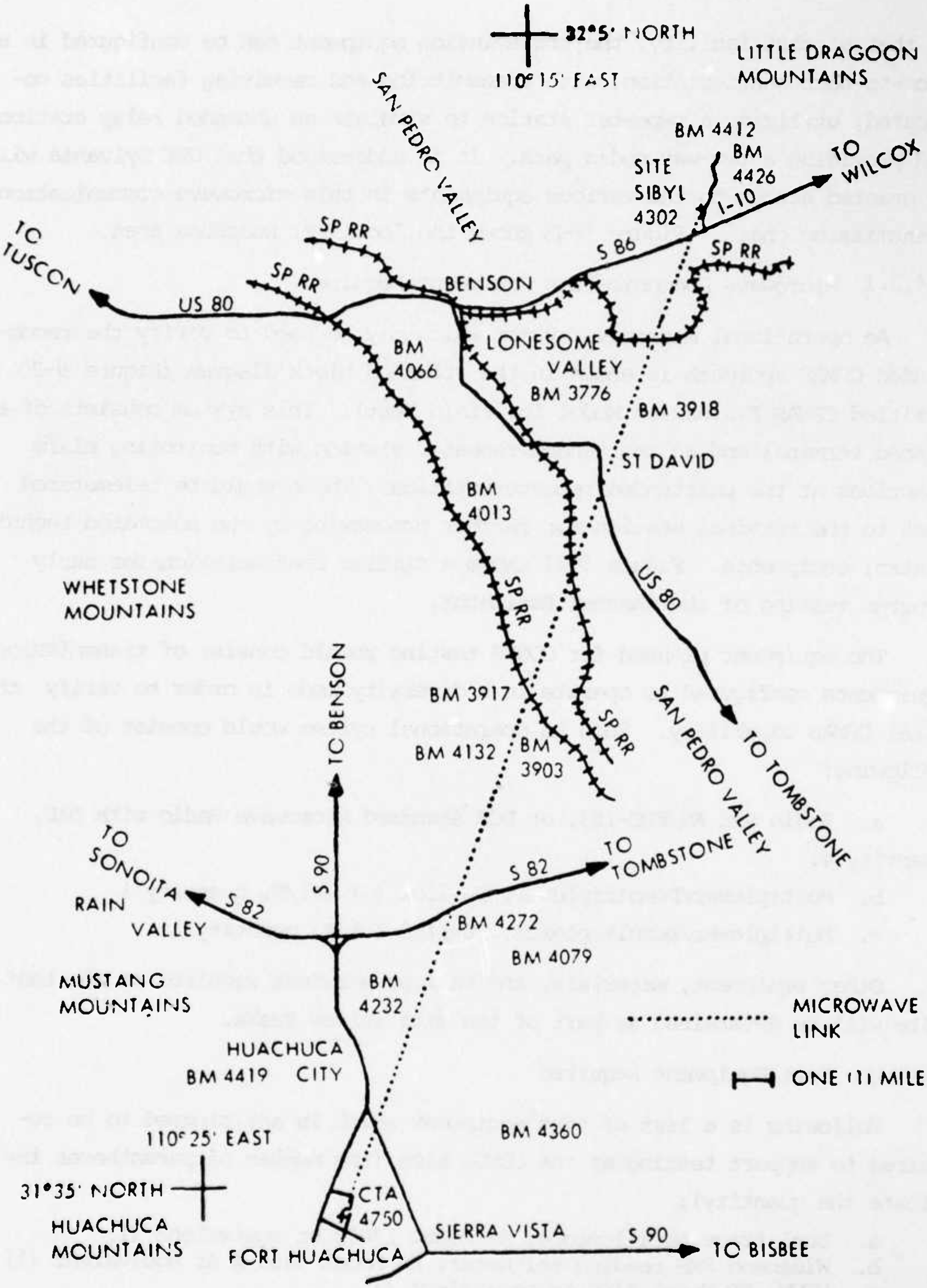


FIGURE 9-19. SIMPLIFIED MAP: CTA TO SITE SIBYL MICROWAVE LINK

CPMAS EVALUATION MODEL FOR FIELD TEST

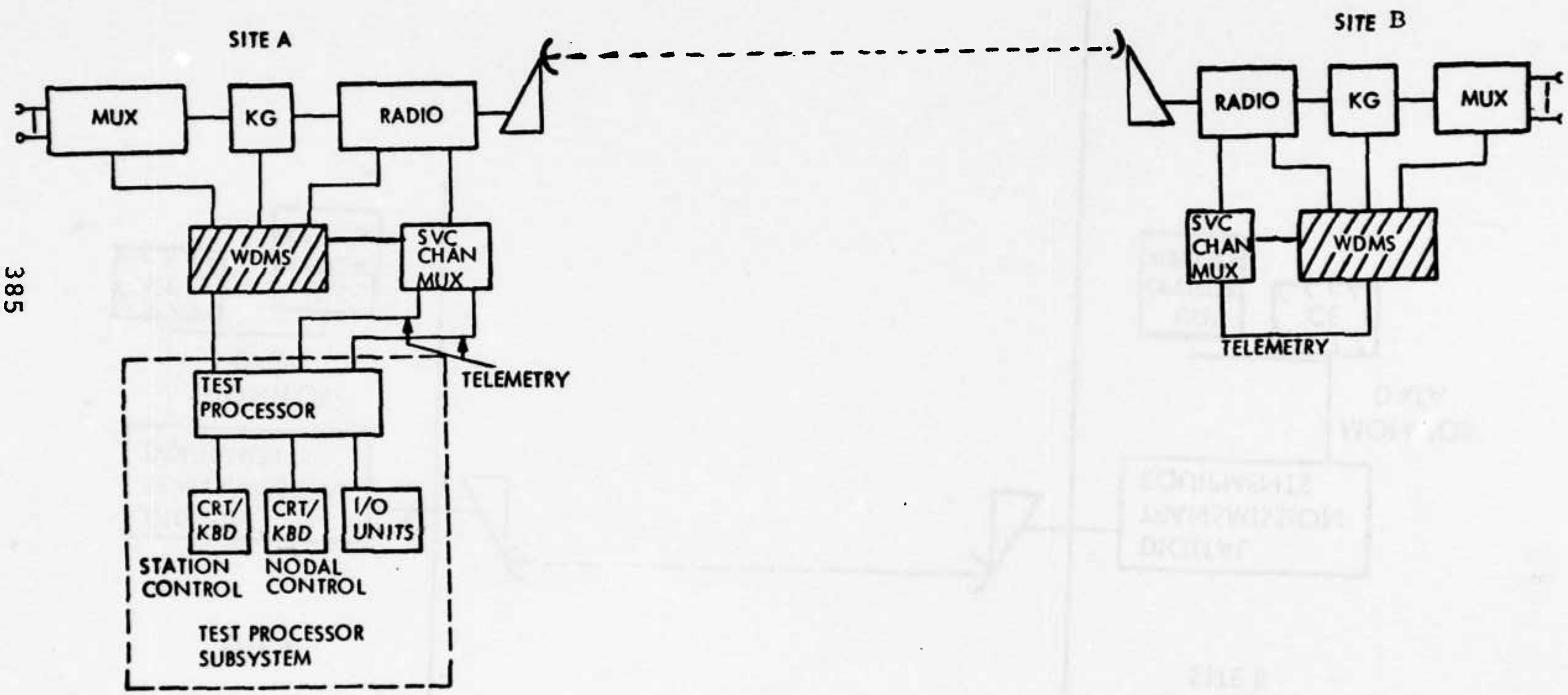


FIGURE 9-20. CPMAS EVALUATION MODEL FOR FIELD TEST

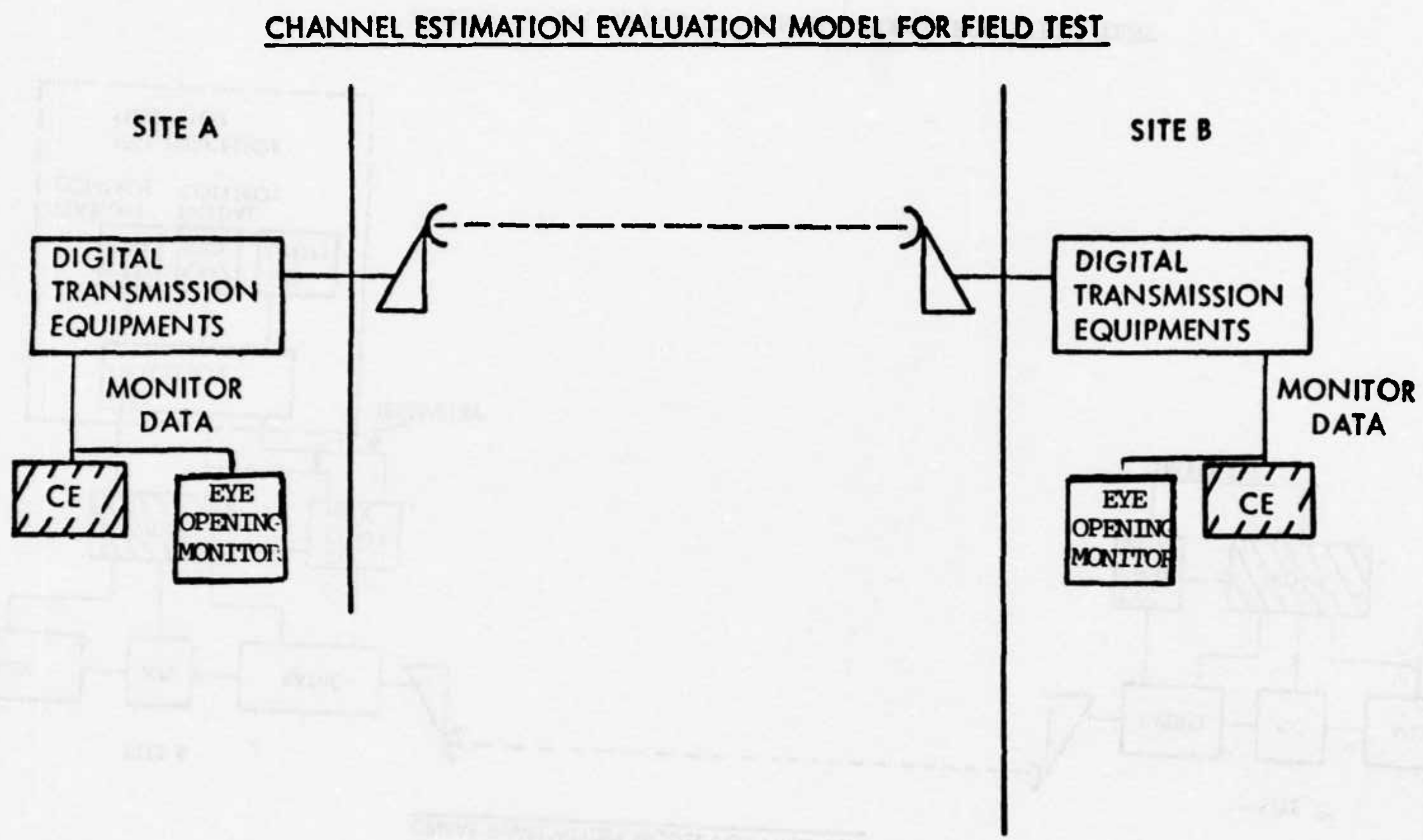


FIGURE 9-21. CE EVALUATION MODEL FOR FIELD TEST

f. Frequency Spectrum Analyzer, HP-Model 141T-System (1)
g. Frequency Counter, HP-Model 5303B (1)
h. Strip Chart Recorder, HP-Model 7132A (1)
i. Sine/Square Wave Generator, HP-Model 209A or equivalent (1)
j. PRBS-Word Generator, HP-Model 3760A or equivalent (1)
k. BER-Detector, HP-Model 3761 A or equivalent (1)
l. Transmission Test Set, HP-Model 3552A or equivalent (1)
m. Portable Test Set, HP-Model 3550 B or equivalent (1)

9.4.3.3 Administration Requirements

The following administrative space and facilities will be required:

a. Office space to accommodate four persons and handtools.

b. One telephone for intrasite and CONUS communications.

c. Access to on-site electronics (repair) facility for performing minor equipment repairs.

d. GTE Sylvania will provide office furnishings as follows (the number in parentheses indicates the quantity):

1. Steel desks (2)
2. Swivel desk chairs (2)
3. Folding chairs (2)
4. File cabinet (1)
5. Storage locker (1)
6. Table (1)
7. Bookcase (1)
8. Blackboard (1)

9.5 Program Plan

GTE Sylvania's Program Plan for the CPMAS Program Option Phase (the Development and Test phases) is shown in Figure 9-22. The plan is based upon sound planning, efficient utilization of technical skills, an effective blend of team skills, and early identification of major risks and key issues. Controls will be implemented to insure that the CPMAS Program:

a. Takes maximum advantage of past and on-going IR&D Programs as they are applicable.

b. Is responsive to developments in the DCS and tactical communication systems.

c. Maintains open information channels with the ATEC contractor.

d. Mantains close liaison with the Government.

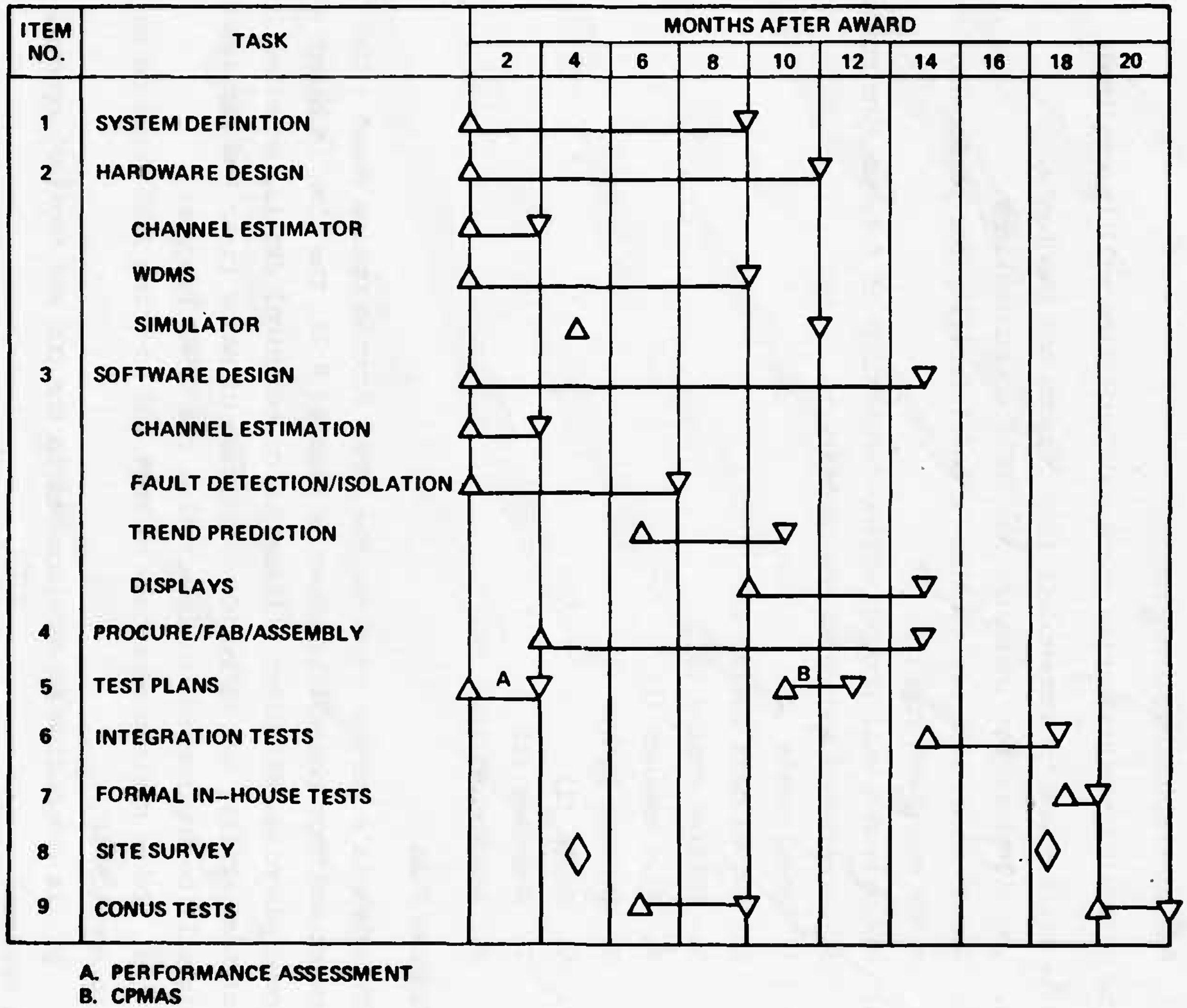


FIGURE 9-22. OPTION PHASE DEVELOPMENT AND TEST PROGRAM

e. Satisfies the technical objectives on schedule.

The GTE Sylvania approach is based on the thorough analysis of the baseline transmission network to define what parameters are required to assess the quality of the digital network. Design goals will be established which insure the modular adaptation to ATEC hardware and software.

The approach recommended to the Government consists of the most cost-effective hardware/software implementations to demonstrate the feasibility of performing performance monitoring, quality assessment, fault isolation, and trend analysis consistent with requirements developed for CPMAS during the study.

Also, it is recommended the development and test of a feasibility model of the Digital Network Control (DNC) Element be considered for future research and development. The DNC Element was extensively defined by GTE Sylvania during the DNC Study Program for DCEC.

The selected alternative will be designed, developed and demonstrated in the most cost-effective manner which will maximize the Program benefits to the Government.

Controls will be implemented throughout the option phase to insure that the data items are prepared in accordance with the CDRL and is reviewed and submitted on schedule. The submission schedule for the data items is presented in Figure 9-23. The CDRLs shown in Figure 9-23 are consistent with tasks recommended for the option phase. The CDRLs listed would apply to either alternative program.

9.5.1 Work Breakdown Structure

The Work Breakdown Structure (WBS) for this program is included in the Cost Volume. The WBS represents the Development, Test, ahd Field Demonstration recommended for the option phase. Within the WBS, work is divided into: Project Management and System Engineering: Project Management Support (oral presentation): the design, development, test, integration and assembly of the selected prime mission hardware/software; the test and field demonstration; the CDRL items, and spares. This WBS defines work elements assignable to line departments at discreet points in the program and forms a basis upon which Task Authorizations are created and the Master Program Plan

B001	R&D STATUS REPORT	MONTHLY
B002	COST/SCHEDULE STATUS REPORT (C/SSR)	QUARTERLY
B003	ABSTRACT OF NEW TECHNOLOGY	AS REQUIRED
B004	CONFIG. ITEM PRODUCT SPEC	PREL. - AT CONCL. OF DESIGN FINAL - 30 DAYS AGC*
B005	C.I. DEVELOPMENT SPEC (SOFTWARE)	PREL - AT CONCL. OF DESIGN FINAL - 30 DAYS AGC
B006	ENGINEERING DATA	AT CONCLUSION OF PROGRAM
B009	TEST REPORTS GENERAL	
B010	TEST PLAN PROC. (EXP. OR ADVANCED DEV.)	PREL - 30 DAYS PRIOR TO START OF TESTS FINAL - 15 DAYS AGC
BC11	TECHNICAL REPORT	AT CONCLUSION OF PROGRAM
BC12	DATA ACCESSION LIST	MONTHLY
B013	SOFTWARE DESCRIPTION DOCUMENT	AT CONCLUSION OF PROGRAM
BC14	CONTRACT FUNDS STATUS REPORT (CFSR)	MONTHLY

FIGURE 9-23. CDRL SUMMARY

is developed.

9.5.2 Make/Buy Plan

Early in the program make/buy requirements will be updated. Table 9-2 and 9-3 present the make/buy requirements.

GTE Sylvania's formal management decision criteria are used concerning sources of supply for all major contractor end items.

The following criteria are considered to establish the basis for a make decision:

a. Capability-experience, skill, and competence on the identified item or similar items within GTE Sylvania.

b. Capacity-availability and adequacy of personnel and facilities within GTE Sylvania.

c. Assigned mission.

d. Performance requirements.

e. Cost to the program.

f. Unavailability from an outside source.

If any element of the above criteria is absent or a make decision is not advantageous to the government, a buy decision is indicated. Make or buy decisions are always made in the best interest of the contract consistent with quality, price, and delivery requirements.

The make/buy decision is made by a make or buy committee consisting of at least the following people: Program Manager, Engineering Task Manager, Director of Engineering, Procurement Manager, and Manufacturing Manager. All decisions are reported to the General Manager.

TABLE 9-2. MAKE/BUY PLAN DEVELOPMENT/TEST PHASE-CPMAS

MAKE/BUY SUMMARY

ITEM	M/B	REC. SOURCES	QTY	LEAD TIME (MOS.)
1. COMPUTER	MB	DEC	1	8
2. MASS MEMORY	MB	DEC	1	4
3. CABINET	MB	EEI	2	2
4. NESTS	MB	AUGAT	4	2
5. CARDS (WIRE WRAP)	MB	AUGAT/MUPAC	29	2
6. POWER SUPPLIES	MB	LAMBDA	2	2
7. DISPLAY TERMINAL/KEYBOARD	MB	DEC	2	8
8. PRINTER	MB	DEC	1	8
9. SCANNER	MB	PULSE COMM	2	4

MB = MUST BUY

MM = MUST MAKE

TABLE 9-3. MAKE/BUY PLAN DEVELOPMENT/TEST PHASE-DNC

MAKE/BUY SUMMARY

ITEM				
1. COMPUTER	MB	DEC	1	8
2. MASS MEMORY	MB	DEC	1	4
3. CABINET	MB	EEI	4	2
4. NESTS	MB	AUGAT	8	2
5. CARDS (WIRE WRAP)	MB	AUGAT	84	2
6. POWER SUPPLIES	MB	LAMBDA	2	2
7. DISPLAY TERMINAL/KEYBOARD	MB	DEC	2	8
8. PRINTER	MB	DEC	1	8
9. SCANNER	MB	PULSE COMM	2	4

MB= MUST BUY
MM= MUST MAKE

SECTION 10
RECOMMENDED RESEARCH AND DEVELOPMENT AREAS

During this study areas that warrant further research and development were identified. These research and development areas would aid in arriving at an optimum CPMAS for the digital transmission system. The four areas recommended for future R&D are: (1) automated digital network control, (2) analysis of restoration/alternate routing procedures in an automated environment, (3) electronic counter counter measures (ECCM), and (4) programmable multiplexer design and development.

10.1 AUTOMATIC DIGITAL NETWORK CONTROL

Digital Network Control provides the technical controller with the ability to reconfigure channels at local and remote stations from a central technical control position. The operations, applications and benefits of digital network control are summarized in Figure 9-1. A detailed discussion of Digital Network Control is presented in Appendix G.

A Digital Network Control System designed during a Digital Network Control Study performed for the Defence Communications Engineering Center (DCEC) provides technical control with automatic channel reconfiguration capability for 64 KB/S and 16/32 KB/S digital channels. A functional block diagram of the Digital Network Control Unit is shown in Figure 9-2. The Digital Network Control Function A (DNC-A) interfaces the DRAMA 1st and 2nd Level Multiplexers at the 1.544 MB/S digital group rate and provides the ability to reassign each individual 64 KB/S channel. The DNC-A also provides local and test channel access.

The DNC-A interfaces with DNC-B via 1.544 MB/S digital groups which contain multiplexed 16 or 32 KB/S digital channels. The DNC-B provides the ability to reassign each 16 or 32 KB/S channel. The DNC-B also interfaces with tactical transmission groups as well as 16/32 KB/S or 2/4KB/S local and test channels.

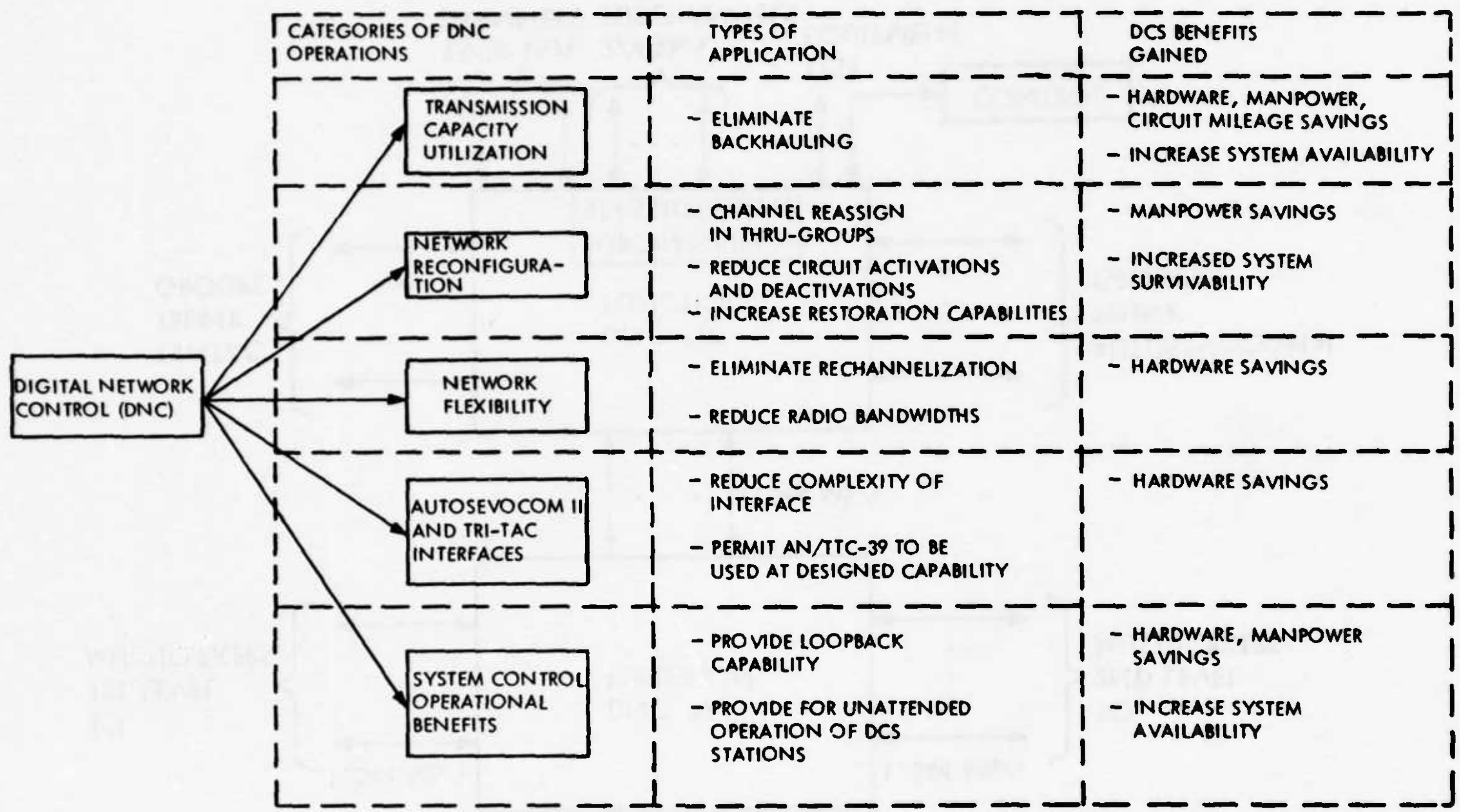


FIGURE 10-1. DIGITAL NETWORK CONTROL APPLICATION SUMMARY

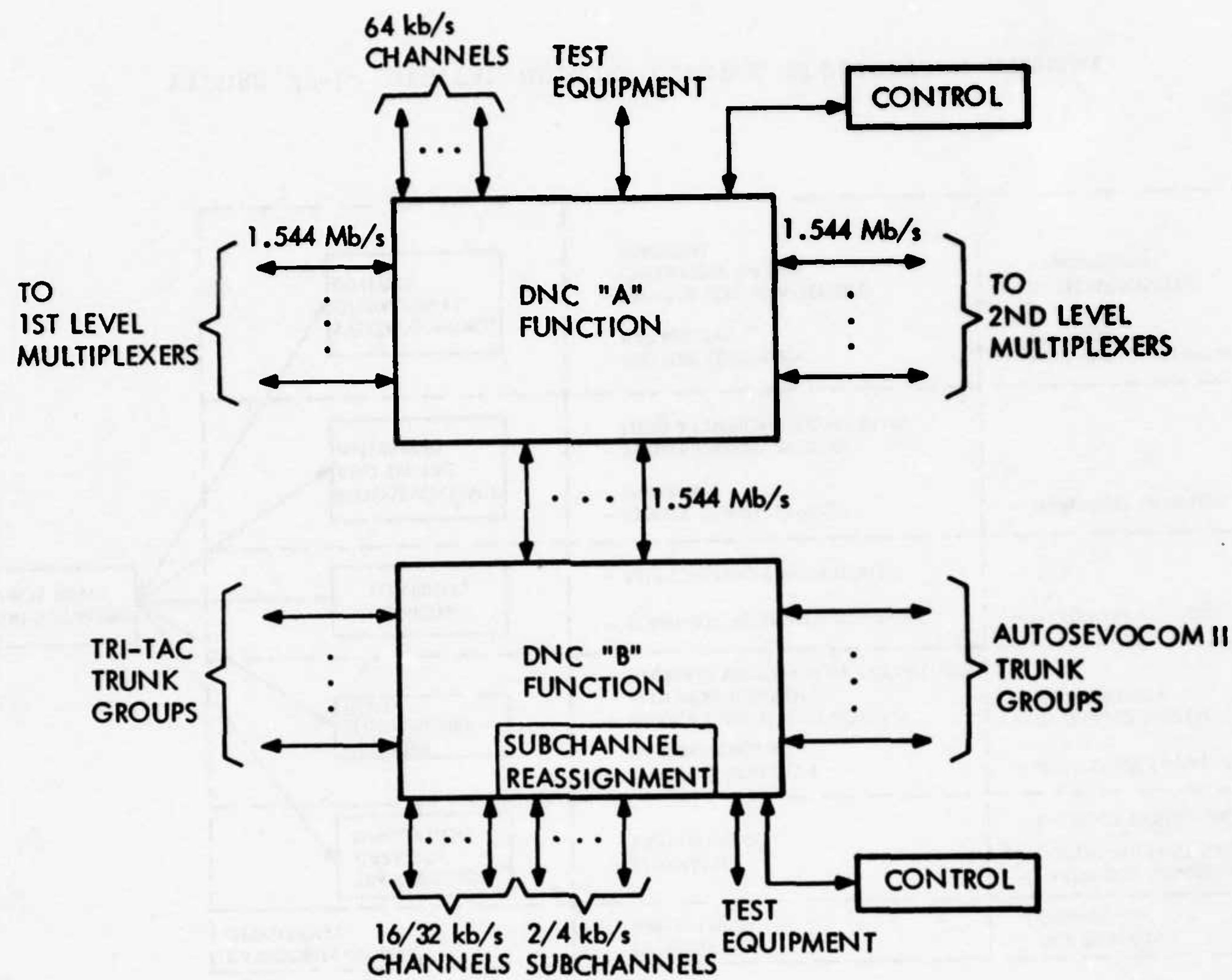


FIGURE 10-2. DIGITAL NETWORK CONTROL FUNCTION DIAGRAM

An evaluation program which would evaluate the application of automatic digital network control to the DCS Digital Transmission System is recommended. The Digital Network Control Field Test Model shown in Figure 9-3 provides the means to evaluate automatic digital network control in a transmission system field environment. The test control processor in the field test model controls the Digital Network Control Units at both the local and remote sites. Remote control of the DNC at Site B is accomplished via a service channel multiplexer telemetry channel.

10.2 Analysis of Restoral/Alternate Routing Procedures in an Automatic Environment

In an automated environment consisting of an automated technical control ATEC capability and a digital network control DNC capability, the procedures for circuit restoral/alternate routing must be strictly defined. The ability to restore circuits and wideband facilities increases with the application of automated techniques. Procedures are required which permit the correlation of the current status of the network with stored restoration plans and which permit the dynamic calculation of restoration plans should the desired routes be unavailable. With ATEC providing automated network assessment and DNC providing automated restoration/alternate routing, the connectivity data bases of the two systems must be efficiently organized. Efficient data base organization will permit smooth integration of these system control automated capabilities.

The scope of work on this R&D program should consist of organizing the connectivity data base at all system control hierarchical levels, determining data base update procedures and controls, and developing the back-up and recovery procedures necessary to assure desired system operation.

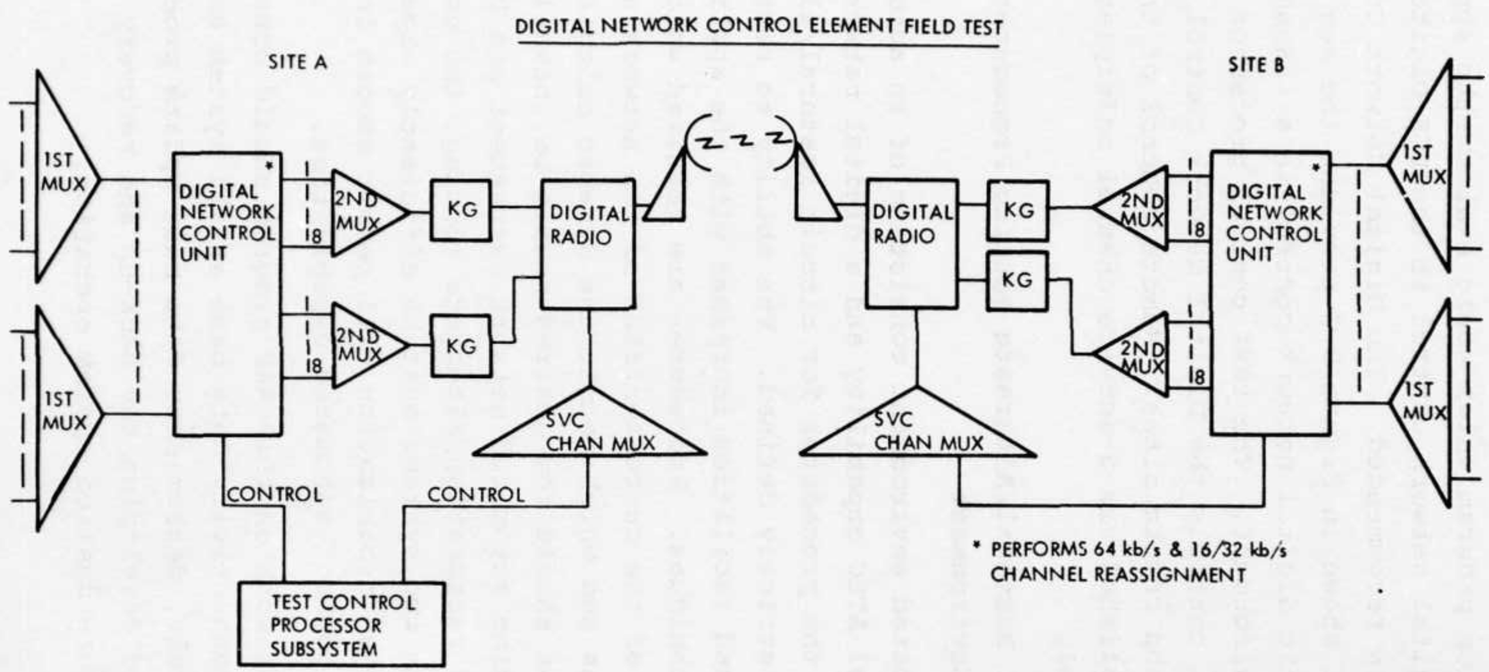


FIGURE 10-3. DIGITAL NETWORK CONTROL FIELD TEST MODEL

10.3 Electronic Counter Counter Measures (ECCM)

Electronic counter measures (ECM) poses a unique technical control problem due to the relative inability of the equipment to detect its presence. The manifestation of ECM in a digital transmission system environment needs further study to define its probable forms and methods that it will be applied. With the added performance assessment capability to be provided by the WDMS, a means may be available to detect and isolate ECM and, thus, allow system control the opportunity to counter the ECM.

The scope of work on this ECCM program should consist of a thorough examination of the manifestations of ECM in a digital environment, the evaluation of modifications and additions to the CPMAS performance assessment technique to detect ECM, and the testing of the ECCM approach.

10.4 Programmable Multiplexer Design and Development

An efficient means of incorporating digital network control into the DCS would be to combine the multiplexing and channel reconfiguration functions in one unit. This would result in what can be called a programmable multiplexer. The programmable multiplexer would require less hardware than the equipment it would replace while increasing the flexibility over that provided by the separate units. Therefore, the programmable multiplexer provides a cost effective means of incorporating DNC into the DCS.

The recommended scope of work on this program consists of developing an efficient programmable multiplexer design based upon the attributes of the DRAMA multiplexer and DNC. This design should be developed and tested to verify the attributes of this approach.

APPENDIX A

DIGITAL TRANSMISSION EQUIPMENT - UNIT DESCRIPTIONS

Appendix A describes the DCS digital transmission equipments which are to be monitored. The DRAMA units described are the TD1193 Second Level Multiplexer, TD1192 First Level Multiplexer, the submultiplexer, the KG-81 Bulk Encryptor, and the DRAMA Radio. Analog equipments discussed are the Analog FM radio, the Digital Applique Unit, the T1-4000 Multiplexer/Demultiplexer, the AN/USC-26 Group Data Modem, the AN/GSC-24 (V) Asynchronous Time Division Multiplexer, and the MD-920/G Modem.

The descriptions are presented here to discuss which monitor points presently exist or are proposed, and to determine the structure so that fault isolation may be performed.

A.1 Second Level Multiplexer

The TD-1193 ( ) (P)/F is a Time Division Multiplexer/ Demultiplexer (TDM) that accepts low data rate (port) inputs from either the TD-1192 ( ) (P)/F First Level Multiplexer, the HY-12, the HN-74, or from the port side of another TD-1193. The TD-1193, described in Figure A-1 and Table A-1, is intended to interface to a KG81 bulk encryptor or to the AN/FRC163 digital radio.

A.1.1 Data Rates

The TDM is configured to operate with from one to eight full duplex ports, each operating at a rate of 1.544 Mb/s ± 200 b/s. Two ports may be strapped together to allow an input of 3.088 Mb/s ± 400 b/s, or four ports may be strapped together to allow an input of 6.176 ± 600 b/s. The relationship between the combined input rates of all ports and the MBS rate is shown:

Combined Input Rate (Mb/s)	MBS Rate (Mb/s)	
1.544	3.232	6.464
3.088	3.232	6.464
4.632	6.464	9.696
6.176	6.464	9.696
7.720	9.696	12.928
9.264	9.696	12.928
10.808	12.928	
12.352	12.928	

A.1.2 Framing

In the asynchronous mode, the TDM accepts the port data and multiplexes it along with framing and bit stuffing information.

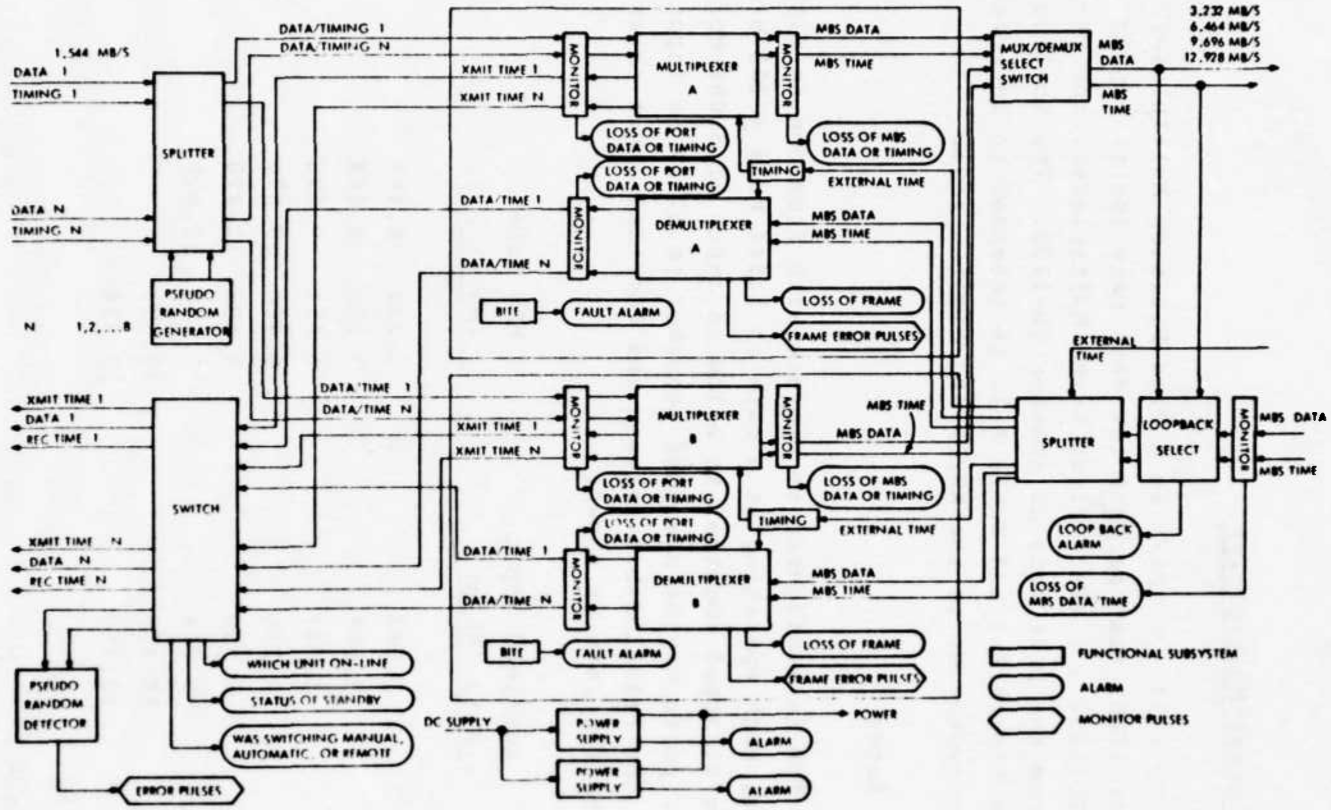


Figure A-1. TD-1193 Second-Level Multiplexer

TABLE A-1. SECOND-LEVEL MULTIPLEX TERMINAL

CONTROLS	EFFECT	TYPE
Select Switch	Selects which redundant multiplexer/demultiplexer	Can be manual, automatic, or remote
Loopback switch	Selects loopback	

A.1.3 Synchronous and Asynchronous Comparison

The TDM can operate with either synchronous or asynchronous ports - the total MBS rate of the TDM is the same independent of whether individual ports are synchronous or asynchronous. Asynchronous input data is asynchronously multiplexed into the output MBS using bit stuffing and/or bit extraction techniques. Synchronous input data is synchronously multiplexed into the MBS using a fixed rate conversion. If synchronous, the TDM provides a source timing output of 1.544, 3.088, or 6.176 MHz for each 1.544 Mb/s, 3.088 Mb/s strapped or 6.176 Mb/s strapped port. In both cases, the TDM accepts a timing signal along with the data.

A.1.4 Redundancy

All functional elements of the TDM are redundant. A functional element is any circuit component whose failure, if not redundant, would result in a circuit outage. This is provided by two complete functional multiplexer/demltiplexer units with appropriate branching and/or switching of the MBS port data and timing signals. Service is restored by switchovers within 100 milliseconds for 97.0% of all service outages. It is also possible to manually and remotely activate this switchover without loss of Bit Count Integrity (BCI) 90% of the time. Total switching time is less than 1 microsecond. If the off-line unit is in an alarmed condition, the switchover does not occur.

A.1.5 Alarms

The TDM has monitor and alarm functions to indicate major system failures and to assist in fault isolation. Lights and remote contact closures are provided for each of the conditions presented in Table A-2.

TABLE A-2. SECOND-LEVEL MULTIPLEX TERMINAL MONITOR/ALARM FUNCTIONS

MONITOR/ALARM FUNCTION	CONDITION	TYPE	NOTE
Power Supply A Power Supply B	Primary Power Applied Primary Power Lost or Protective Device Failed	Form C Lamp On Open Lamp Off Closed	Separate Alarms for Both Power Supplies
Loss of Port Input A Loss of Port Input B	Loss of Input Data or Timing	Form C Alarm Red Light	
Loss of Port Output A Loss of Port Output B	Loss of Demultiplexer Output Data or Timing	Form C Closure Red Light	
Loss of Mux Output A MBS Loss of Mux Output B MBS	Loss of Mux Output Data or Timing before the combiner and loopback	Form C Closure Red Light	One Alarm for each Multiplexer; if Mux transmits data again, remote alarm opens
Loss of Demux Input MBS	Loss of Demux Input Data or Timing	Form C Closure Red Light	One Alarm for both demux's Monitors loss of loopback if loopback on; if receive data, remote alarm opens
Fault Alarm A Fault Alarm B	Failure in BITE	Form C Closure Red Light	Separate Alarms for each Demultiplexer; when fault is corrected, remote alarm is deactivated.

TABLE A-2. SECOND-LEVEL MULTIPLEX TERMINAL MONITOR/ALARM FUNCTIONS (Cont.)

MONITOR/ALARM FUNCTION	CONDITION	TYPE	NOTE
Loss of Frame A Loss of Frame B	Demux is not in frame or framing circuitry fails	Form C Closure Red Light	If frame synchronization is acquired, both red light and remote closure are deactivated.
Frame Error Monitor A Frame Error Monitor B	Framing bit error in MBS input to Demux	Pulse for each error; light flashing at rate proportional to BER or meter	
Loopback Alarm	Loopback is on caused by front switch or external TTL command	Form C Closure White Light	
Monitor Switchover			
1) Which is on-line	A or B	Light; Form C	
2) Failure is off-line		Light; Form C	
3) Type of switching	Manual, remote or automatic	Light; Form C	

A.1.5.1 Power Supply Monitor and Alarm. A light is deactivated and an alarm closes whenever primary dc power is lost or a protective device fails. Alarms are provided for both the main and standby power supplies.

A.1.5.2 Loss of Frame Alarm. An alarm operates whenever the demultiplexer is not in frame or timing to the framing circuitry fails. If the demultiplexer reacquires frame synchronization, the alarm is deactivated. Separate alarms are provided for each demultiplexer.

A.1.5.3 Loss of MBS Output Alarm. An alarm operates when the TDM fails to transmit either MBS data or MBS timing for 100 milliseconds or more. If the MBS transmits data or timing, the alarm is deactivated. Separate alarms are provided for each multiplexer.

A.1.5.4 Loss of MBS Input Alarm. An alarm operates when the TDM fails to receive MBS data or timing for 100 milliseconds or more. If the TDM receives MBS data or timing, the alarm is deactivated. Only one alarm is provided for the entire TDM.

A.1.5.5 Loss of Port Alarm. An alarm operates when any TDM port fails (loss of digital data--no transitions for 100 milliseconds or more) to output digital signals to the common equipment or output a digital signal to the port output connector. These are four alarms: One for the on-line multiplexer, one for the off-line multiplexer, one for the on-line demultiplexer, and one for the off-line demultiplexer.

A.1.5.6 Fault Alarm. An alarm is activated whenever a failure of the TDM is detected by the Built-In Test Equipment (BITE). The BITE monitors dc power supply voltages, go-no-go fault location functions and all critical internal and external circuitry. Separate alarms are provided for the on-line and standby multiplexer/demultiplexer sets.

A.1.5.7 Switchover Monitor and Alarm. Remote switches indicate (a) which multiplexer/demultiplexer is on-line, (b) the occurrence of any detected failure of the standby multiplexer/demultiplexer, and (c) whether the switching action was manually, remotely, or automtically initiated.

A.1.5.8 Loopback. An alarm indicates the TDM MBS output is looped back internally to the TDM. The loopback is initiated either remotely or by a switch on the front of the TDM.

A.1.5.9 Frame Error Pulses. A pulse is provided at a connector whenever an error occurs in the framing bits.

A.1.6 Pseudo-Random Generator Detector

The TDM can transmit pseudo-random digital data over a single port of the TDM at a rate of 1.544 Mb/s ± 200 b/s for the purpose of making bit error rate measurements at the receive port. Errors in the transmitted bit stream are detected at the receive end and error pulses are routed through a connector. The pseudo-random shift register has a length of at least 20 bits and has a self-check made by generating a fixed amount of errors at the transmit end and detecting the amount at the receive end.

A.2 First Level Multiplexer

The TD-1192 ( ) (P)/F Time Division Multiplexer/ Demultiplexer, shown in Figure A-2, accepts low data rate traffic or voice frequency analog signals and multiplexes these into a Mission Bit stream of up to 1.544 Mb/s, suitable for use in TD-1193 second level multiplexer, the KG-81 Trunk Encryption Device, the AN/GSC-24 and the T1-4000.

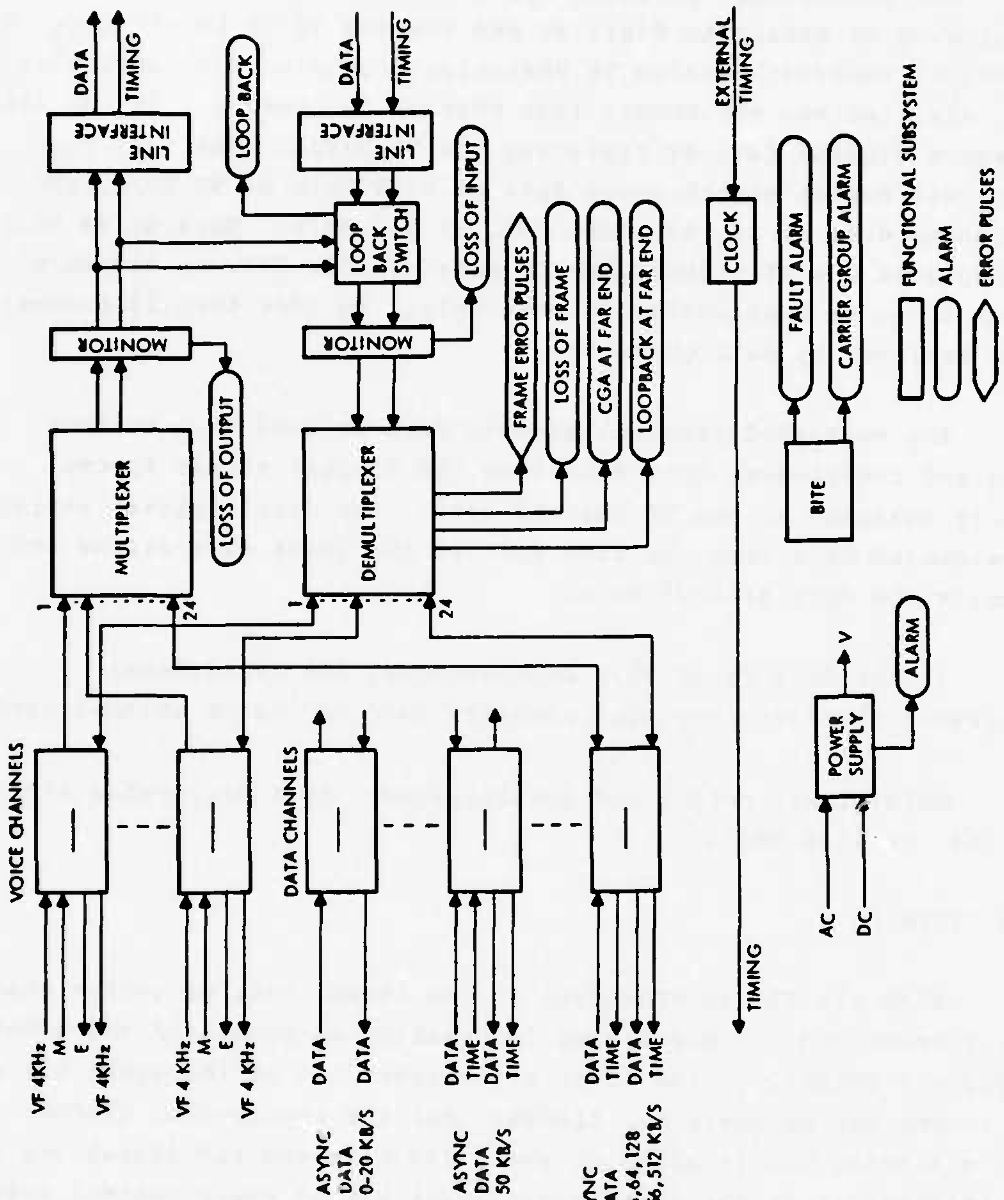


Figure A-2. TD-1192 First-Level Multiplexer

A.2.1 Date Rates

The multiplexer performs A/D conversion and time division multiplexing necessary to digitize and combine up to twenty-four, 4 kHz nominal bandwidth analog VF channels, providing A/D conversion in three, six, twelve, and twenty-four channel increments. It can also interleave digital data by replacing the VF cards. The unit can accept full duplex asynchronous data at 0-20 Kb/s or 50 Kb/s, and synchronous data at 56, 64, 128, 256, or 512 Kb/s. Data at 64 Kb/s or less replaces one VF channel, while data at 128, 256, or 512 Kb/s replace 2, 4, or 8 channels, respectively. No more than 12 channels can be replaced by data channels.

The multiplex terminal accepts data at 0-20 Kb/s without timing and interleaves this data into the digital stream spaces normally assigned to one VF channel card. The demultiplexer extracts this wideband data from the time slot in the input data stream and transmits the data at 0-20 Kb/s.

If the data is 50 Kb/s asynchronous, the multiplexer interleaves this into the slot normally used by one VF channel card.

Multiplexer output and demultiplexer input data rates are 192, 384, 768, or 1544 Kb/s.

A.2.2 Framing

When the TDM is operating in the three, six, or twelve channel mode, framing and E&M signalling information is generated and added to the digital output, in the least significant bit of the eight bit code word in one out of every six frames. For the twenty-four channel mode, a framing bit is added to every 192 bits and E&M signalling is submultiplexed into the least significant bit of every channel every sixth frame. Framing and E&M signalling information is extracted and used at the demultiplexer.

A.2.3 Alarms

The multiplex terminal has monitor and alarm functions to indicate system failures and assist in fault isolation. Lights and remote contact closures are provided for all the conditions presented in Table A-3.

A.2.3.1 Power Supply Monitor and Alarm. A light is deactivated and an alarm operates whenever primary ac or dc power is lost or a protective device fails.

A.2.3.2 Loss of Frame Alarm. An alarm operates when the demultiplexer is not in frame or timing to the framing circuitry fails. If the demultiplexer reacquires frame synchronization, the alarm is deactivated.

A.2.3.3 Loss of Output Alarm. An alarm operates when the multiplexer fails to transmit data or timing (no transition for 100 milliseconds or more). If the multiplexer transmits data or timing, the alarm is deactivated.

A.2.3.4 Loss of Input Alarm. The data and timing from the multiplexer can be looped back internally to the multiplexer by means of either a switch accessible from the front of the multiplex terminal or an external TTL level command. When the terminal is looped back, an alarm is activated, and a bit stream of all ones is sent to the far end multiplex terminal, causing an alarm on the far end. Separate alarms are provided to indicate whether the loopback was initiated at the near end or far end.

A.2.3.6 Carrier Group Alarm. Whenever one of the following conditions occur - power supply alarm, loss of output alarm, loss of input alarm, loopback alarm, or loss of frame alarm for 300 milliseconds - the carrier group alarm is activated. All transmit data channel bits are forced to one, and an alarm is activated. Also,

TABLE A-3. FIRST-LEVEL MULTIPLEXER ALARM OPERATIONS

MONITOR/ALARM FUNCTIONS	CONDITION	INDICATION		OUTPUT DATA STREAM
		FRONT PANEL	REMOTE ALM. CKT.	
POWER SUPPLY MONITOR AND ALARM	PRIMARY POWER-APPLIED	LAMP ON	OPEN (OFF)	
	PRIMARY POWER-LOST OR PROTECTIVE DEVICE-FAILED	LAMP OFF	CLOSED (ON)	
FRAME LOSS-ALARM	DEMPLXR-NOT IN FRAME OR FRAMING CIRCUITRY TIMING-FAILED	RED LAMP ON**	CLOSED	
OUTPUT LOSS-ALARM	MPLXR-FAILS TO TRANSMIT DATA OR MPLXR-FAILS TO TRANSMIT TIMING FOR 100 MS OR MORE	RED LAMP ON**	CLOSED	
INPUT LOSS-ALARM	DEMPLXR-FAILS TO RECEIVE DATA OR DEMPLXR-FAILS TO RECEIVE TIMING FOR 100 MS OR MORE	RED LAMP ON**	CLOSED	

**ALARM OPERATION SHALL BE SUCH THAT IF THE CONDITION IS REMOVED, THE RED LAMP IS DEACTIVATED (OFF)

TABLE A-3. FIRST-LEVEL MULTIPLEXER ALARM OPERATIONS (Cont.)

MONITOR/ALARM FUNCTIONS	CONDITION	INDICATION		OUTPUT DATA STREAM
		FRONT PANEL	REMOTE ALM. CKT.	
LOOPBACK-ALARM	MPLXR-DATA/TIMING OUTPUTS SWITCHED TO DEMPLXR DATA/TIMING INPUTS INTERNAL LOOPBACK EFFECTED VIA FRONT PANEL SWITCH OR REMOTE COMMAND TTL LEVEL	WHITE LAMP ON	CLOSED	BIT STREAM (ALL ONES IN EVERY BIT POSITION INCL. FRAMING BIT POSITIONS) TRANSMITTED FOR DURATION OF LB MODE
CARRIER-GROUP ALARM	MPLX TERMINAL ALARM(S) (ONE OR MORE) - ON POWER SUPPLY ALARM OR OUTPUT LOSS ALARM OR INPUT LOSS ALARM OR LOOPBACK ALARM OR FRAME LOSS ALARM IF DURATION 300 $\pm$100 M SEC	WHITE LAMP ON	CLOSED	ALARM PATTERN: 2ND BIT EVERY PCM WORD FORCED TO ZERO (FOR DURATION ALARM)
LOOPBACK AT FAR END ALARM	ALL ONE'S DETECTED IN BIT STREAM	WHITE LAMP ON	CLOSED	
CARRIER GROUP ALARM AT FAR END	ALARM PATTERN DETECTED	WHITE LAMP ON	CLOSED	

TABLE A-3. FIRST-LEVEL MULTIPLEXER ALARM OPERATIONS (Cont.)

MONITOR/ALARM FUNCTIONS	CONDITIONS	INDICATION		OUTPUT DATA STREAM
		FRONT PANEL	REMOTE ALM. CKT.	
FAULT ALARM	BITE-DETECTED FAILURE IN MULTIPLEX TERMINAL (GO/NO-GO FAULT LOCATION TO ISOLATE FAILURE TO PARTICULAR PLUG IN CARD OR PLUG IN MODULE; NOT REQUIRED FOR VF CHANNEL PLUG IN CARDS)	RED LAMP ON**	CLOSED	
FRAME ERROR MONITOR	ERROR(S) DETECTED IN DEMPLXR INPUT FRAMING PATTERN	PULSE PROVIDED (AT MPLX TERMINAL CONNECTOR) WHEN EACH ERROR DETECTED		

**ALARM OPERATION SHALL BE SUCH THAT IF THE CONDITION IS REMOVED, THE RED LAMP IS DEACTIVATED (OFF)

if there is loss of input or loss of frame for 300 milliseconds, a pattern is sent to the far end causing carrier group alarm (CGA) at that terminal. Separate alarms are provided to indicate whether the CGA was initiated at the near-end or far-end terminal.

A.2.3.7 Fault Alarm. An alarm is activated whenever a failure is detected by the Built-In Test Equipment (BITE). The BITE monitors, measures, and tests signals in and out of the equipment and the internal circuits, including dc voltages and go-no-go fault locator circuitry. Once the fault is corrected, the alarm is deactivated.

A.2.3.8 Frame Error Monitor. Framing bits in the data input to the demultiplexer are monitored for errors, and a pulse is provided at a connector when each error occurs.

A.3 Submultiplexer

The DRAMA system has two types of submultiplexers. The TDM-1251 submultiplexer is an example of one; Figure A-3 gives its block diagram.

A.3.1 Applications

The higher speed of the two submultiplexers, designated level A, is intended to interface with the TD-1192 first level multiplexer. The slower, Level B submultiplexer, inputs data into the Level A submultiplexer, or into the first level multiplexer. The details of the Level B submultiplexer are not yet specified.

A.3.2 Data Rates

The Level A submultiplexer combines three 16 Kb/s digital synchronous bit streams plus an overhead bit stream into a single 56 Kb/s digital bit stream or combines seven 16 Kb/s or three 32 Kb/s synchronous digital streams plus a suitable overhead bit stream into a single 128 Kb/s digital bit stream. The overhead bit streams are, in

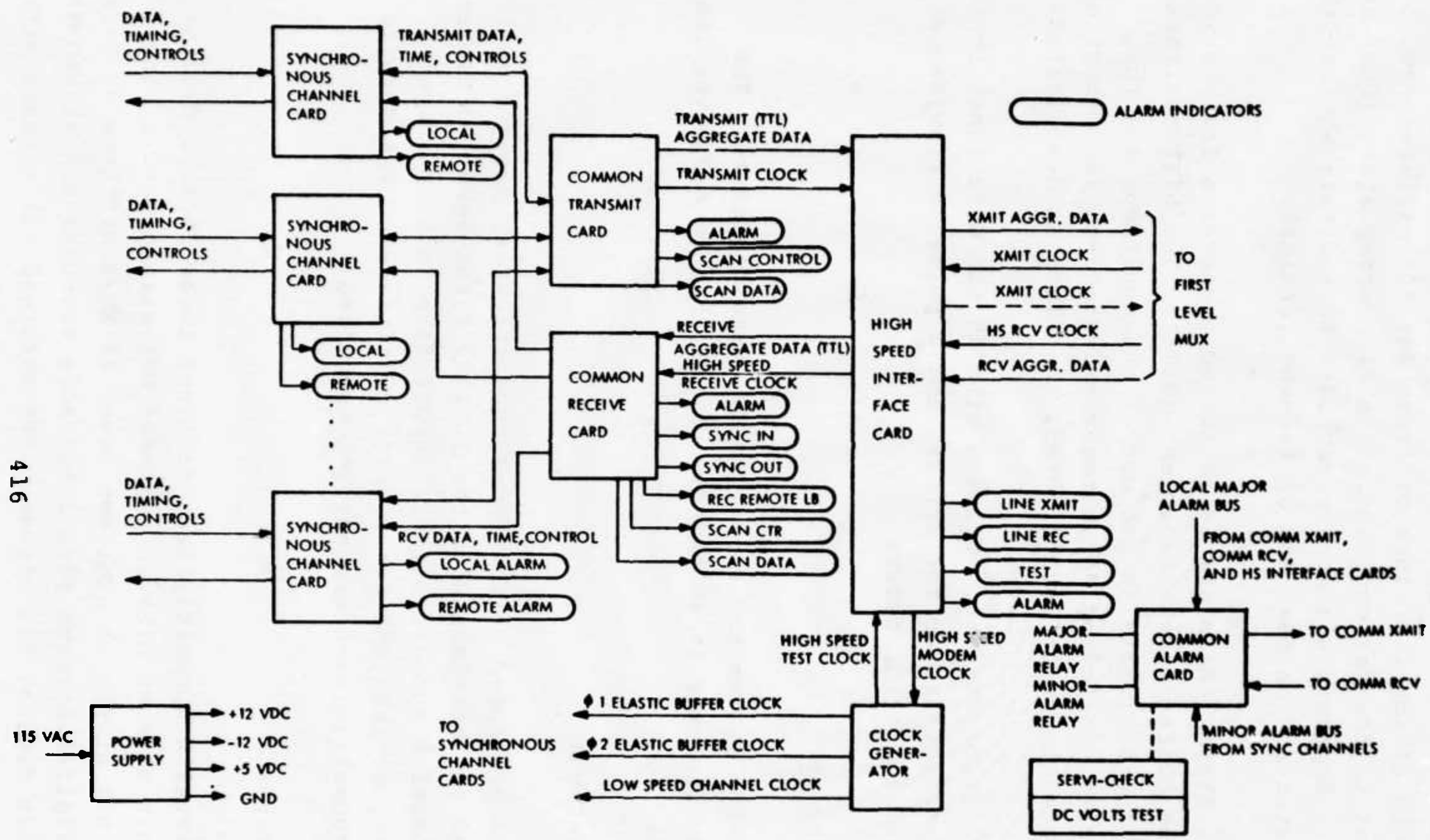


Figure A-3. TDM 1251 Submultiplexer Block Diagram

each case, an 8000N b/s bit stream, synchronous with the traffic bit streams. The submultiplexer interfaces with the 56 Kb/s and 128 Kb/s input/output ports on the first level multiplexer.

The Level B submultiplexer can accept synchronous data rates of 75×2^N b/s, N = 0, 1 ... 7, asynchronous rates of 45.5, 50 and 74.2 b/s, and isochronous rates of 37.5, 56.8, 61.1, and 75 b/s. The high speed side of the Level B submultiplexer can interface with the 16 Kb/s part of a Level A submultiplexer, or the 56 Kb/s or 64 Kb/s ports of the first level multiplexer. The number of ports on the Level B submultiplexer are not yet specified.

A.3.3 Structure and Alarms

Each card on the TDM-1251 Submultiplexer has built-in test equipment and local and remote alarms to indicate hardware failures. some cards have additional alarms to aid in isolation of faults that may cause alarms on several cards.

A.3.3.1 Synchronous Channel Card. The submultiplexer has a separate synchronous channel card for each low-speed channel. The card provides line interface, controls, and timing. The card has local and remote alarms.

A.3.3.2 Common Transmit Card. Each submultiplexer has one common transmit card. This card receives data, timing, and controls from the synchronous channel cards, interleaves the data, adds framing, and sends data and clock to the high-speed interface card. It has remote and local alarms, an alarm to indicate the channel scan for transmit control is malfunctioning, and an alarm to indicate the channel scan for transmit data is malfunctioning.

A.3.3.3 Common Receive Card. Each submultiplexer has one common receive card. This card receives data and clock from the high-speed interface card, demultiplexes the data, extracts framing information, and sends data, timing, and controls to the synchronous channel cards.

It has an alarm indicator, an indicator for in-sync condition, an indicator for out-of-sync condition and TDM start-up, an indicator for a loopback initiated by the remote TDM, an indicator for a malfunction in the channel scan for receive control, and an indicator for a malfunction in the channel scan for receive data.

A.3.3.4 High-Speed Interface Card. Each unit has one high-speed interface card. This card interfaces the lines to the first level multiplexer with the common transmit card, common receive card, and clock. It has an alarm, a line loopback diagnostic test mode indicator, an alarm for transmit data or transmit clock, and an alarm for receive data or receive clock.

A.3.3.5 Clock Generator Card. The clock generator card derives and synchronizes output frequencies from the high-speed modem receive clock, and provides a system test clock (for local TDM checkout) at the high-speed clock rate.

A.3.3.6 Common Alarm Card. The common alarm card provides alarm indication, SERVI-CHECK indication, and power supply test points. If a major alarm occurs in the TDM, the common alarm card generates and sends a major alarm bit to the common transmit card for transmission to the remote TDM; minor alarms are transmitted to the remote TDM from the synchronous channel card. Major alarm bits from the remote TDM are relayed to the common alarm card. The common alarm card SERVI-CHECK panel produces visual and audible indication of TDM card test point signals. DC voltages from the power supply can be monitored on the common alarm card.

A.3.3.7 Power Supply. The power supply accepts 115 V AC and generates voltages of + 12 V DC, - 12 V DC, and + 15 V DC. The voltages can be monitored on the common alarm card.

A.3.4 Fault Isolation

The submultiplexer has a fault isolation table to isolate many of the common failures, the patterns of operations being shown in Table A-4. By using the alarms and indicators, the controller can isolate to one card if it detects loss of transmit clock, loss of transmit data, channel scan control malfunction in receive data, channel scan control malfunction in receive control, channel scan control malfunction in transmit data, channel scan control malfunction in transmit control, loopback tests, buffer data slipage, TDM out-of-sync, loss of receive clock, and loss of receive data.

A.4 Bulk Encryptor

The bulk encryption device accepts digital data streams and timing at digroup or higher rates and provides encryption of that data stream. The encryptor will be used in this system at 1.544 Mb/s, 3.088 Mb/s, 6.176 Mb/s, 9.264 Mb/s, and 12.352 Mb/s. The encryptor could be used at the output of the TD-1192 or the TD-1193.

A.5 Radio Systems

This section presents the radio systems which might be used for transmitting and receiving digital signals over line of sight paths in the transmission network.

The radios can be either (a) digital or (b) analog. A digital radio includes a digital modulator/demodulator (modem) for directly encoding the discrete and abrupt DC level changes of digital binary baseband signals onto a carrier. In contrast, transmission of digital information over analog FM radios requires a subsidiary equipment such as a Digital Applique Unit (DAU) to spectrally condition the binary signal by carefully designed coding and filtering which eliminates the abrupt digital level changes prior to analog transmission.

TABLE A-4. SUBMULTIPLEXER ALARM INDICATOR OPERATION

ALARM CONDITION	CARD	ORIGINATING SITE INDICATIONS	REMOTE SITE INDICATIONS
Loss of Transmit Clock	Common Transmit	a. ALARM On b. SCAN Data/Ctrl (off)	-
	High Speed Interface	a. ALARM On b. LINE Xmt (off)	-
	Common Receive	-	a. SYNC Out b. SCAN Data/Ctrl (off) c. ALARM On
	Common Alarm	Loc and Rmt, MAJOR ALARM	Loc and Rmt, MAJOR ALARM
Loss of Transmit Data (Line out of TDM to Transmission Equipment (Modem) broken)	Common Receive	-	a. SYNC Out b. ALARM On c. SCAN Data/Ctrl (off)
	High Speed Interface	-	a. ALARM On b. LINE Roy (off)
	Common Alarm	Rmt, MAJOR ALARM	Loc, MAJOR ALARM
Channel Scan Control Malfunction, receive data	Common Receive	a. SCAN Data (off) b. ALARM On	-
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM
Channel Scan Control Malfunction, receive control	Common Receive	a. SCAN Ctrl (off) b. ALARM On	-
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM

TABLE A-4. SUBMULTIPLEXER ALARM INDICATOR OPERATION (Cont.)

ALARM CONDITION	CARD	ORIGINATING SITE INDICATIONS	REMOTE SITE INDICATIONS
Channel Scan Control Malfunction, transmit data	Common Transmit	a. SCAN Data b. ALARM On	-
	Common Receive	-	a. SYNC Out b. ALARM On c. SCAN Control (off)
	Common Alarm	Loc and Rmt, MAJOR ALARM	Loc and Rmt, MAJOR ALARM
Channel Scan Control Malfunction, transmit control	Common Transmit	a. SCAN Ctrl b. ALARM On	-
	Common Receive	-	a. SYNC Out b. ALARM On c. SCAN Control (off)
	Common Alarm	Loc and Rmt, MAJOR ALARM	Loc and possible Rmt MAJOR ALARM
Remote Line Loopback Test	High Speed Interface	(TEST EXT if initiated by EIA interface signal)	a. TEST Line b. ALARM
	Common Receive	-	a. TEST Rcv Rmt LB b. ALARM
	Common Alarm	Rmt, MAJOR ALARM	Loc, MAJOR ALARM

TABLE A-4. SUBMULTIPLEXER ALARM INDICATOR OPERATION (Cont.)

ALARM CONDITION	CARD	ORIGINATING SITE INDICATIONS	REMOTE SITE INDICATIONS
Aggregate Loopback Test	High Speed Interface	a. (TEST EXT if initiated by EIA interface signal) b. ALARM On	-
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM
Internal Loopback Test	Sync Channel with control card	ALARM Loc	ALARM Rmt
	Common Alarm	MINOR ALARM	MINOR ALARM
Remote Loopback Test	Sync Channel with control card	ALARM Loc	ALARM Rmt
	Common Alarm	MINOR ALARM	MINOR ALARM
Channel Elastic I/O Buffer Data Slippage	Sync Channel	ALARM Loc (blinks)	-
TDM Out of Synchronization	Common Receive	a. SYNC Out b. ALARM On	-
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM
Loss of Receive Clock	Common Receive	a. ALARM On b. SYNC Out c. SCAN Data/Ctrl (off)	- -

TABLE A-4. SUBMULTIPLEXER ALARM INDICATOR OPERATION (Cont.)

ALARM CONDITION	CARD	ORIGINATING SITE INDICATIONS	REMOTE SITE INDICATIONS
Loss of Receive Clock (Cont.)	High Speed Interface	a. ALARM b. LINE Rev (off)	
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM
Loss of Receive Data	Common Receive	a. ALARM On b. SYNC Out c. SCAN Data/Ctrl	- - -
	High Speed Interface	a. ALARM On b. LINE Rcv (off)	- -
	Common Alarm	Loc, MAJOR ALARM	Rmt, MAJOR ALARM

NOTE

Other malfunction indicators, such as SYNC OUT and both control and data scans can be out depending on magnitude of malfunction.

Both types of radios can accomplish the same function of transmitting the binary type signals produced by either data equipment or voice digitizers. A given digital transmission network of multiple links can thus include a mixture of digital and analog radios. The main prerequisite for system compatibility is that a receiving set of one type at a link end must operate with a transmitter of the same type at the other link end. An illustration of compatible network operation for a mixture of radio types is shown in Figure A-4. This diagram depicts a multiple-link network containing three types of radios which are considered for use in DCA systems. These are:

a. DRAMA type digital radio per specification CCC-74049.

b. FKV type system using an analog FM radio such as the AN/FRC-162 and subsidiary digital equipments such as the T1-4000 second level mux, the CY-104 first level mux with KG-34 encryption equipment, and the T1SB1 digital data mux.

c. Analog radio system using the AN/FRC-162 FM radio and the Digital Applique Unit (DAU).

The digital radio is discussed next, and the analog radio system (including the DAU) is described in Section A.5.2.

A.5.1 Digital Radio

DRAMA specification CCC-74049, including amendments, sets forth the requirements for microwave digital radios in the 4- and 8-GHz bands with which the CPMAS system should operate. The actual implementation of the digital radio is not known at this time because the contract has not been awarded. For the purposes of this study, a typical or generic implementation is postulated and investigated. The main alternatives in the implementation lie in the modulation/ demodulation approach, therefore this aspect of the radio design is

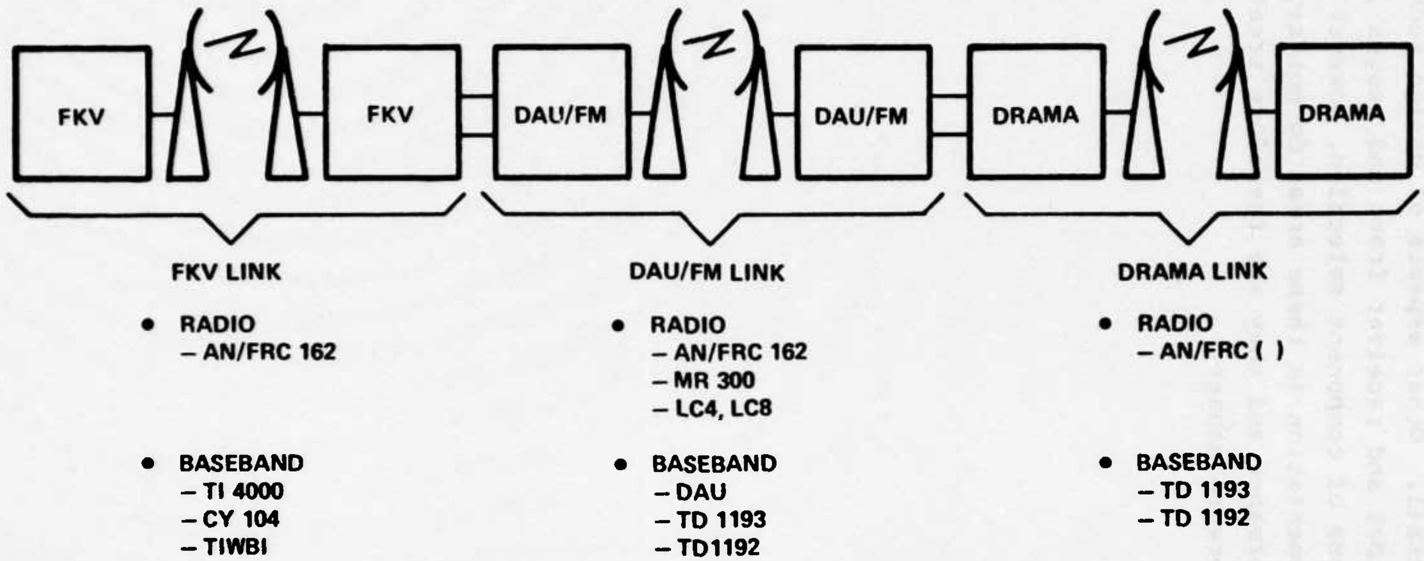


Figure A-4. Digital Transmission System

considered in some detail. Other aspects of design such as transmitter power output and receiver front end stages involve numerous considerations of component selection, however the alternatives to implementation in these areas do not significantly alter the radio performance and they are therefore treated in a relatively straightforward manner.

A.5.1.1 Functional Description

The DRAMA radio is comprised of a number of components, as listed in Table A-5.

TABLE A-5. COMPONENTS OF DRAMA RADIO SETS

QUANTITY	ITEM
2	Receivers
2	Transmitters
2	Time Division Multiplexers
2	Power Supplies
Ass'y	Waveguide Components
Ass'y	Fault Sensing and Alarm Circuits
Ass'y	Performance Monitoring Equipment

The DRAMA radio has a number of optional capabilities depending upon frequency, bit rate, emitted bandwidth, power output and terminal arrangements. These options are summarized in Table A-6.

TABLE A-6. DRAMA RADIO OPTIONAL CAPABILITIES

CAPABILITY	OPTIONS
Frequency	4.4-5.0-GHz and 7.125-8.40-GHz Bands
Mission Bit Stream Rate	3.232, 6.464, 9.696, 12.918 MBPS
Total MBS Rate	3.232, 6.464, 9.696, 12.928, 19.392, 25.856 MBPS
Transmitted Bandwidth	3.5, 7.0, 10.5, 14.0, 20.0 MHz
Power Output	100 mw; 2 W with Power Amplifier
Terminal Configuration	Frequency or Space Diversity

Basically, the function of the digital radio is to input and output two synchronous mission bit streams (MBS), or a single MBS, at the rates selected from Table A-5, and a service channel bit stream (SCBS) at 192 KBPS, each with associated timing. The ability to handle one or two MBS and the SCBS is provided by the internal mux/demux which is built into the radio set.

The main interfaces of the digital radio are with the equipments listed in Table A-7.

TABLE A-7. DRAMA RADIO INTERFACES

TYPE	DESCRIPTION
TD-1193( )(P)/F	DRAMA Second-level mux
TD-1192( )(P)/F	DRAMA Voice and data mux for 192-KBPS Service Channel
AN/GSC-24(V)	Defense Communications Systems Multi-Channel Mux
KG-81	Encryption Equipment

The digital radio shall also be capable of interfacing with an external clock input at the MBS rate of the radio internal multiplexer. Clock outputs at the MBS and SCBS rates will be provided by the radio, phase locked to the radio transmit clock.

At the RF end, the digital radio interfaces with the antenna system through an RF branching network. The antenna system is not considered part of the radio set. The exact radio configuration and the RF interface depends upon whether the radio set is used as either a frequency diversity or space diversity terminal. In a frequency diversity terminal, one RF interface to a single antenna is required, and the two transmitters (timed to different frequencies) are transmitting at all times; the two receivers are tuned to another pair of frequencies.

In a space diversity terminal, the two transmitters are tuned to one common frequency, the two receivers are tuned to another common frequency, and two separate diplexed antenna system interfaces are provided.

Figure A-5 shows the radio set configured for both frequency diversity and space diversity operation. This figure also discloses the functional redundancy inherent in the design. Switchover actions between components occur due either to equipment failures or propagation disruptions. The monitoring and assessment of these switching actions, and the monitoring and assessment of the condition of both the hot and standby equipments are included in the technical control requirements.

As mentioned earlier, one of the main determinants of digital radio system performance is the modulation and coding technique. The options which appear to be open to the DRAMA radio designer are therefore discussed next.

A.5.1.2 Modulation Schemes

The modulation techniques which can meet the transmitted bandwidth requirements of the DRAMA specification (CCC-74049, Specification for Radio Set, AN/FRC-( )( ), 1 March 1976 with Amendments, July 1976) are those that achieve transmitted bandwidth efficiency of 1 to 2 Bps/Hz. Other than this system requirement for data rate/bandwidth combinations, no particular type of carrier modulation is specified for the radio set. Hence any modulation technique which can achieve the specified bandwidth efficiencies is possible, although some modulation schemes are more efficient, easier to implement, and/or flexible enough to accommodate a wide range of bandwidth efficiency.

Those modulation techniques that can achieve the required bandwidth efficiency are summarized in Table A-8. They are grouped as to the theoretical bandwidth efficiency they can realize with a 100%

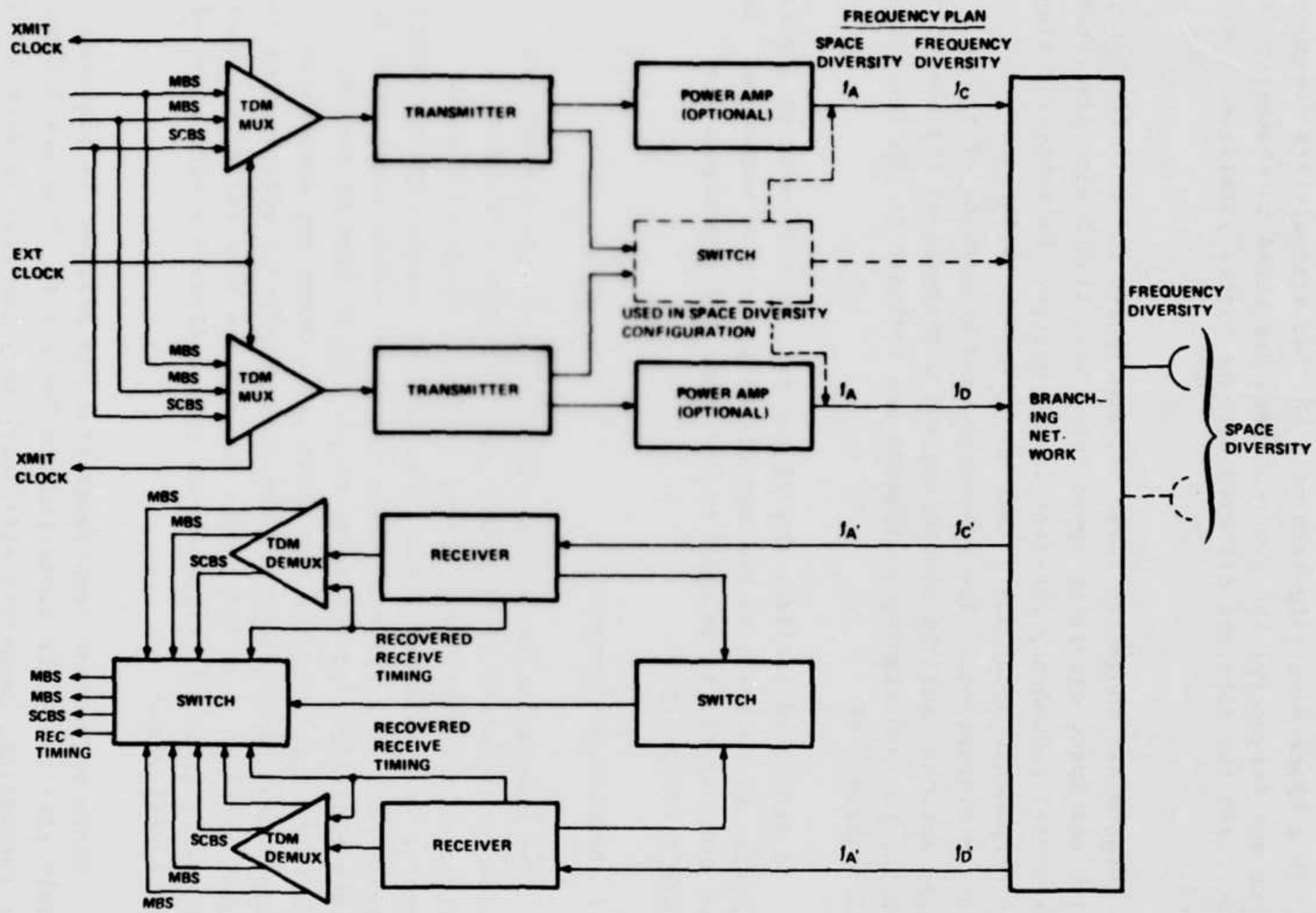


Figure A-5. DRAMA Radio Configuration for Space and Frequency Diversity

TABLE A-8. CANDIDATE RADIO MODULATION TECHNIQUES

BANDWIDTH EFFICIENCY (Bps/Hz)	MODULATION TECHNIQUE
1.0	QUATERNARY PSK QUATERNARY FM THREE-LEVEL PR/PSK OR FM
1.5	OCTAL PSK OCTAL FM
2.0	QUATERNARY QAM THREE-LEVEL PR/QAM SEVEN-LEVEL PR/PSK OR FM

roll-off factor. Three- and seven-level Partial Response radios, which could be used in conjunction with the analog FM radio, are discussed in detail later. They are included here for ease of reference and comparison. Other modulation techniques or their variations are possible, but only those that are known to have been developed or proposed for microwave digital radio systems are included in the table.

The bandwidth efficiencies in the table are nominal values which have been derived assuming baseband signal shaping of 100% relative excess bandwidth. Their values can therefore be modified considerably by baseband signal shaping and/or passband filtering. For example, one digital radio set on the market is stated to have bandwidth efficiency of 2.26 Bps/Hz using octal PSK on a single carrier. Obviously, by decreasing the excess bandwidth of the baseband signals, one can increase the efficiency of the transmitted bandwidth. At the extreme, signal shaping exactly at the Nyquist bandwidth, i.e., no excess bandwidth, can achieve twice the efficiency that is possible with 100% relative excess bandwidth. However, since such a signal is very sensitive to symbol-timing error, a design between these two values is usually employed in practice. Also, a reduced bandwidth of a passband filter increases the efficiency, but it in turn increases intersymbol interference at the receiver, thus lowering the detection margin against noise.

By incorporating PR coding, a digital modulation technique can double the bandwidth efficiency. The most popular PR codes are duobinary and modified duobinary. Since PR coding is a baseband technique which can be used with any carrier modulation scheme and, more importantly, it may have to be employed at such a digital equipment as the DAU in order to meet the stringent bandwidth requirements, its discussion will be deferred until later.

In summary, the candidate modulation techniques for the digital radio are: Quaternary or octal PSK or FM, and QAM with up to

16 signal points (quaternary QAM). Each modulation scheme may be preceded by PR coding to increase the bandwidth efficiency.

Performance assessment techniques which monitor the demodulated baseband signal, such as the eye-opening technique, the adaptive channel estimation technique, and the jitter monitor technique, can be used for any modulation scheme which employs a coherent demodulation process. Since PSK and QAM systems mostly adopt coherent demodulation, these techniques are appropriate for such a system. Even though a digital FM system often performs non-coherent demodulation using a limiter/discriminator due to its implementation advantage, these techniques can still be applied for performance assessment.

The pseudo-error rate technique can be utilized for any modulation scheme regardless of the demodulation process. Various modulation schemes would simply require modification of the decision thresholds. The parameters which should be modified to obtain pseudo-error rates are the phase in PSK, the amplitude and the phase or, equivalently, the radial distance and the angle in QAM, and the demodulator output value in digital FM.

Among the error counting techniques, frame error counting is done at a demultiplexer and hence is not affected by the choice of carrier modulation. The format violation technique can be used only when PR coding or any other data-signal formatting is employed in the system. Table A-9 summarizes various performance assessment techniques vs. modulation method in a Matrix Table.

A.5.1.3 Block Diagram

A detailed functional block diagram of a digital radio set is shown in Figure A-6. The monitor and test points are shown in Table A-10, depending on the particular modulation technique employed and specific implementation schemes used at the radio, the block diagram

TABLE A-9. PERFORMANCE ASSESSMENT TECHNIQUES FOR VARIOUS MODULATION METHODS

PERFORMANCE ASSESSMENT TECHNIQUE	MODULATION TECHNIQUE							
	1.0 Bps/Hz			1.5 Bps/Hz		2.0 Bps/Hz		
	QUATERNARY PSK	QUATERNARY FM	3-LEVEL PR/ PSK OR FM	OCTAL PSK	OCTAL FM	QUATERNARY QAM	3-LEVEL PR/QAM	7-LEVEL PR/ PSK OR FM
EYE-OPENING	X	X	X	X	X	X	X	X
ADAPTIVE CHANNEL ESTIMATION	X	X	X	X	X	X	X	X
PSEUDO-ERROR RATE	X	X	X	X	X	X	X	X
JITTER MONITOR	X	X	X	X	X	X	X	X
ERROR COUNTER (NOTE A)	X	X	X	X	X	X	X	X
FORMAT VIOLATION			X				X	X
RECEIVED SIGNAL LEVEL	X	X	X	X	X	X	X	X

NOTES: A. USUALLY PERFORMED IN MUX.

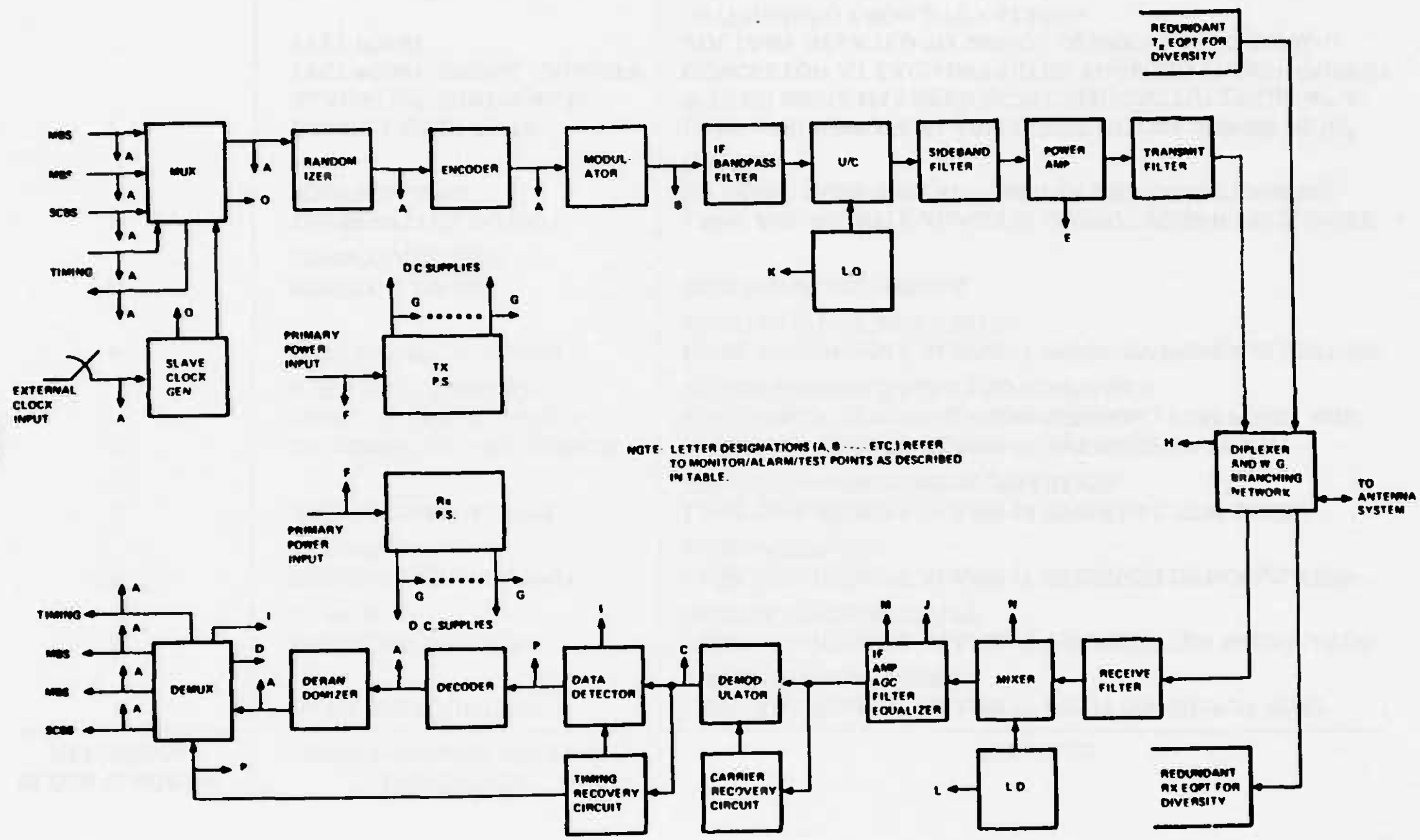


Figure A-6. DRAMA Radio Functional Block Diagram

TABLE A-10. DRAMA RADIO TYPICAL CPMAS MONITOR/TEST POINTS

BLOCK DIAGRAM REFERENCE	MONITORED CONDITIONS/PARAMETERS	REMARKS
A	DATA INPUT/OUTPUT	LAMP AND REMOTE ALARM IF INPUT OR OUTPUT PORT LOSES DATA OR TIMING.
B	MODULATOR OUTPUT ALARM	LAMP AND REMOTE ALARM IF TRANSMITTER MODULATOR OUTPUT LOSES ACTIVITY.
C	DEMODULATOR OUTPUT ALARM	LAMP AND REMOTE ALARM IF RECEIVER DEMODULATOR LOSES ACTIVITY.
D	RADIO FRAME ALARM	LAMP AND REMOTE ALARM IF INTERNAL TDM LOSES RECEIVE FRAME SYNCHRONIZATION.
E	TRANSMITTER FREQUENCY DRIFT ALARM; P/A VOLTAGES AND CURRENTS	LAMP AND REMOTE ALARM IF AVERAGE TRANSMIT FREOUENCY DEVIATES FROM NOMINAL; TEST POINT AND METER FOR VOLTAGES AND CURRENCY.
F	POWER SUPPLY ALARM	LAMP AND REMOTE ALARM IF PRIMARY POWER IS LOST OR PROTECTIVE DEVICE FAILS.
G	DIRECT CURRENT SUPPLY VOLTAGE	TEST POINT AND METER.
H	TRANSMITTER OUTPUT POWER ALARM	LAMP AND REMOTE ALARM IF OUTPUT POWER DECREASES BY MORE THAN 3 dB; ALSO METER DISPLAYS TRANSMIT POWER.
I	FRAME ERROR RATE ALARM, BIT ERROR RATE TEST POINT, SIGNAL QUALITY TEST POINT	LAMP AND REMOTE ALARM IF BER OF ONE ERROR IN 10^4 BITS OR MORE HAS BEEN DETECTED; OUTPUT PULSE AT A CONNECTOR AT EACH DETECTED FRAMING ERROR; OUTPUT VOLTAGE RELATED TO SNR OR DEMODULATED SIGNAL DETERMINED FROM EYE PATTERN.
J	RECEIVED SIGNAL LEVEL TEST POINT	DC VOLTAGE WHICH IS LINEARLY PROPORTIONAL TO THE RSL IN dBm.

TABLE A-10. DRAMA RADIO TYPICAL CPMAS MONITOR/TEST POINTS (CONT.)

BLOCK DIAGRAM REFERENCE	MONITORED CONDITIONS/PARAMETERS	REMARKS
K	TRANSMITTER LO VOLTAGES	TEST POINT AND METER.
L	RECEIVER LOCAL OSCILLATOR AND AFC VOLTAGES/CURRENTS	TEST POINT AND METER.
M	RECEIVER AGC VOLTAGE	TEST POINT AND METER.
N	RECEIVER MIXER CURRENTS	TEST POINT AND METER.
O	OVERHEAD MONITOR POINTS	LAMP AND ALARM IF NOT FUNCTIONING CORRECTLY.
P	JITTER MONITOR POINTS	LAMP AND ALARM IF EXCEEDS TOLERANCE.
Q	CLOCK MONITOR POINTS	LAMP AND ALARM TO MONITOR FREQUENCY, DRIFT, AND NOISE.
–	TERMINAL STATUS	VISUAL INDICATORS WHICH DETAIL THE EQUIPMENT STATUS OF EACH RECEIVER; TRANSMITTER, AND POWER SUPPLY AS WELL AS THE DIVERSITY SWITCH STATUS IF SWITCHING DIVERSITY IS USED. WHEN MAINTENANCE SWITCH PLACES EITHER TRANSMITTER OR RECEIVER IN OFF-LINE STATUS, A LIGHT WILL INDICATE THE OFF-LINE CONDITIONS.

may have to be modified slightly. However, the basic structure will typically apply to any radio set as far as performance monitoring and assessment are concerned.

The internal multiplexer accepts and synchronously time-division-multiplexes one or two Mission Bit Streams (MBS) and a single Service Channel Bit Stream (SCBS), each with associated timing. The randomizer scrambles the output bit stream of the multiplexer to minimize discrete spectral components in the transmitted spectrum.

The encoder may consist of three stages of different coding schemes aside from the binary-to-multilevel conversion. A PR encoder is employed in order to condition the power spectral density of the transmitted signal. When the modulation is PSK and the receiver is to extract the carrier synchronization from the received data signal, differential encoding is necessary to resolve the phase ambiguity at the carrier recovery circuitry of the receiver. If the modulation is multilevel, then it is beneficial in terms of bit-error rate to encode the symbols using a Gray code.

At the modulator, the bit or symbol stream(s) modulate the phase (in PSK) or frequency (in FM) of the carrier, or amplitudes of the two carriers in quadrature (in QAM). Then the data signal is un-converted, amplified and filtered as necessary, sometimes through several stages in cascade.

The receiver mostly "undoes" the processing that the data signal went through at the transmitter. The received RF signal is filtered and down-converted, using the local oscillator. The IF signal is then amplified, filtered, and equalized if so designed, in order to make the signal most appropriate for demodulation and detection. When coherent demodulation is to be done, auxiliary circuitry is needed to provide the carrier. If the modulation technique is either PSK or QAM, the carrier and the timing signal can be recovered directly from the data signal. When non-coherent de-modulation is performed as in the limiter/discriminator of digital

FM, no carrier recovery scheme is necessary. In some systems, a pilot tone which is frequency-division-multiplexed with the data signal is extracted by a narrow bandpass filter for the purpose of synchronization. The detected data bit or symbol stream is decoded and de-randomized, and respective MBS and SCBS are separated at the internal time-division-demultiplexer.

A.5.2 Analog Radio Systems

Investigation of the CPMAS requirements for digital transmission via analog radio includes the microwave FM radio plus the baseband equipment which interfaces it. The baseband section contains coding, modulation and filtering equipment.

Figure A-7 shows the general scheme of digital transmission with analog radios, and the two specific cases which have been considered in this investigation. These are the FKV analog radio, which uses the Vicom T1-4000 as the baseband section and the Collins AN/FRC-162 FM radio, and the DAU/FM radio, which uses the Digital Applique Unit specified as MD-1007/G for the baseband section, and a number of possible equipments such as the AN/FRC-162 or the Motorola MR-300 and Ford-Aerospace LC-4 and LC-8 series for the FM radio. The transmission capabilities of the two systems differ, normally 12 MBPS for the FKV system and approximately double this rate for the DAU/FM radio.

The FM radios used in these systems are straightforward in design and have been in operational use for some time. The main interfacing considerations concern proper connection to the FM deviator/modulation amplifier and the output of the limiter/discriminator or the IF amplifier. The design approach to the baseband section involves some special considerations.

In order to meet the rather stringent transmitted bandwidth efficiency requirement - one or two Bps/Hz in the RF band - some spectrum conditioning scheme is employed in the baseband in addition

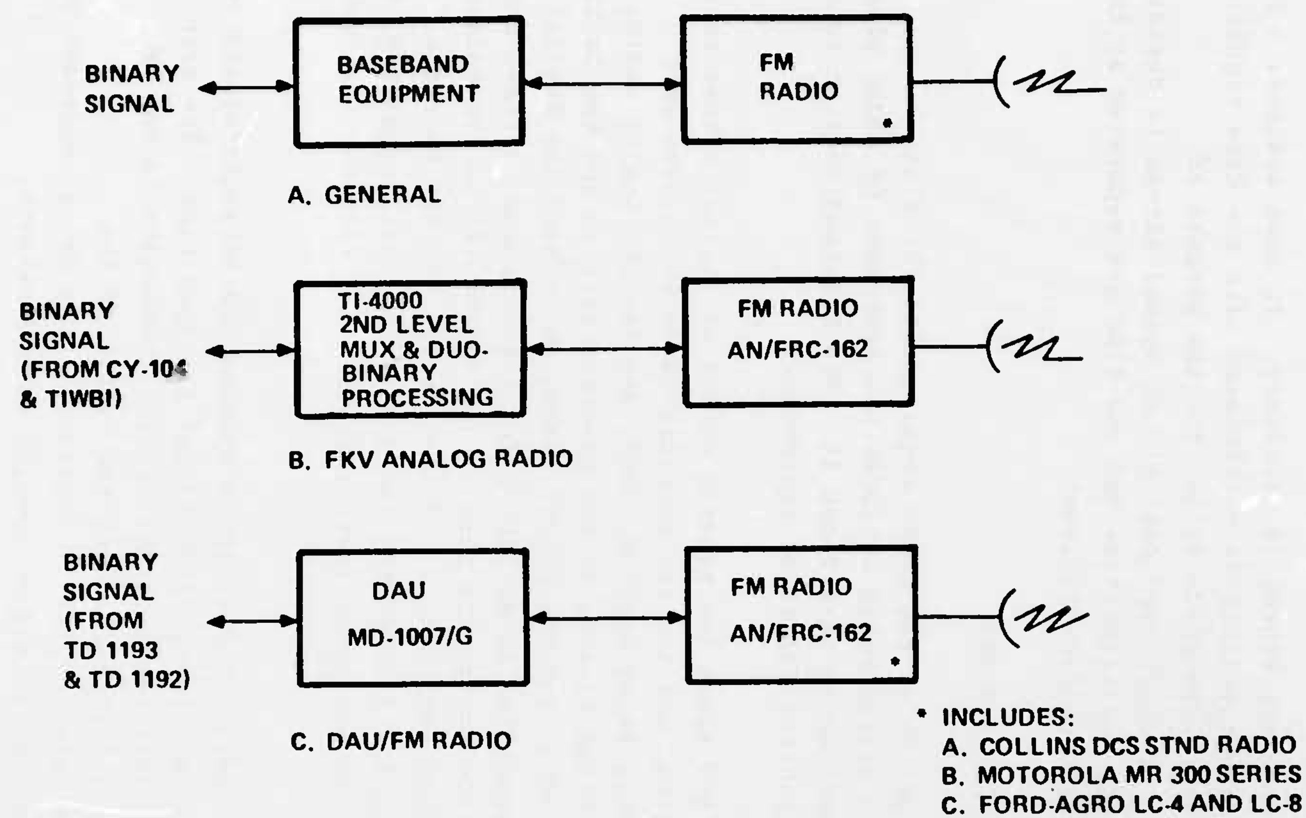


Figure A-7. Types of Analog Radio Systems for Digital Transmission

to multilevel signalling and near-Nyquist-bandwidth signal shaping. One easy and very effective scheme is PR coding. (It is also called PR signalling when it is effected through signal shaping rather than through digit encoding. The digit encoding approach is described because it illuminates the whole procedure more clearly.)

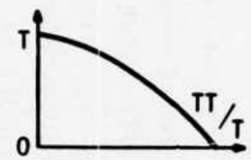
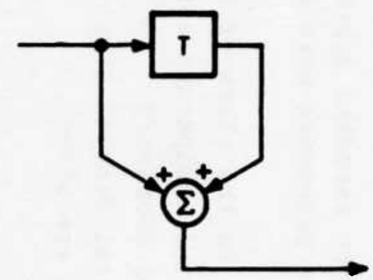
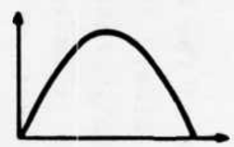
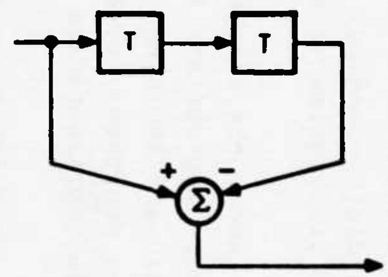
Among the various codes in the class of PR, two schemes seem to be more appropriate for digital equipments such a the DAU. One is duobinary and the other modified duobinary. In Table A-11, their transfer functions, power spectral density shaping functions and possible implementation schemes are shown.

From the power spectral density shaping functions, the advantages of using these PR codes can be seen. They suppress the signal power spectrum gradually at the band edges, thus enabling faster signalling. They have spectral nulls at the Nyquist frequency which can be used for sending an orderwire or a pilot tone.

Each of the above PR coding schemes outputs three-level signals for binary inputs, or seven-level signals for quaternary inputs. This increase in output levels incurs a small penalty in signal-to-noise ratio, 2.1 to 3.3 dB depending on the implementation scheme. However, owing to controlled correlation between the symbols, error detection and correction can simply be accomplished without introducing redundant digits.

The following paragraphs will further analyze the design and the CPMAS monitor and test point requirements for the FKV and DAU/FM radio systems. First the FM radio is covered; the AN/FRC-162 is taken as a typical example which is representative of various FM radios which might be used. Then, the digital baseband equipment (DAU and T1-4000) is covered. It is noted that the T1-4000 used with the FKV system is an operational production equipment and is therefore subject to firmer definition than the DAU at this time. The DAU is still undergoing research development and specification.

TABLE A-11. FUNCTIONS AND IMPLEMENTATION OF TWO PR-CLASS CODES

PR TYPE	TRANSFER FUNCTION F(D)	SPECTRAL DENSITY SHAPING FUNCTION $\lvert H(\omega)\rvert$	POSSIBLE DIGITAL IMPLEMENTATION
DUOBINARY (CLASS I)	$1 + D$		
MODIFIED DUOBINARY (CLASS IV)	$1 - D^2$		

A.5.2.1 Analog FM Radio

The FM radio in the FKV system is the AN/FRC-162(V) radio set. In future systems, there is the possibility of choosing from the Collins DCS Standard Radio (equivalent to the AN/FRC-162), the Aeronutronic Ford LC Series Radio, and the Motorola AF/FRC-80 (MR 300) Series Radio. In the following, we give a detailed description of the AN/FRC-162 radio only; it is representative of all the above analog FM radios. The differences in implementation between various radio sets are insignificant as far as system performance monitoring and assessment are concerned.

A functional block diagram of the AN/FRC-162 radio set is shown in Figure A-8. There are three types of input signals: (1) the transmit baseband signal from the T1-4000 (in the FKV) or the DAU (in the DEB), (2) the voice order wire (VOW) which covers from 300 Hz to 3000 Hz, and (3) the supervisory order wire which covers from 4 KHz to 8 KHz. The transmit baseband signal is passed through a bandstop filter which eliminates spectral components from 8.0 MHz to 8.5 MHz in order to accommodate a pilot at 8.5 MHz and the service channel at 8.1 MHz later. The VOW and the supervisory order wire are combined at the audio channel unit into a service channel. The service channel modulates an 8.1 MHz subcarrier. The baseband signal is coupled to the modulation amplifier where the service channel is added.

The composite baseband signal from the modulation amplifier modulates the frequency of the intermediate carrier. The modulated IF carrier from the basic oscillator is then coupled to a 2-GHz amplifier. The AFC unit is used here to control the center frequency of the basic oscillator.

The amplified IF signal is coupled to two stages of frequency doubler to generate the final output carrier. The modulated signal is filtered and fed into the waveguide diode switch where a switchover to the hot standby transmitter takes place in the event of the in-service transmitter failure.

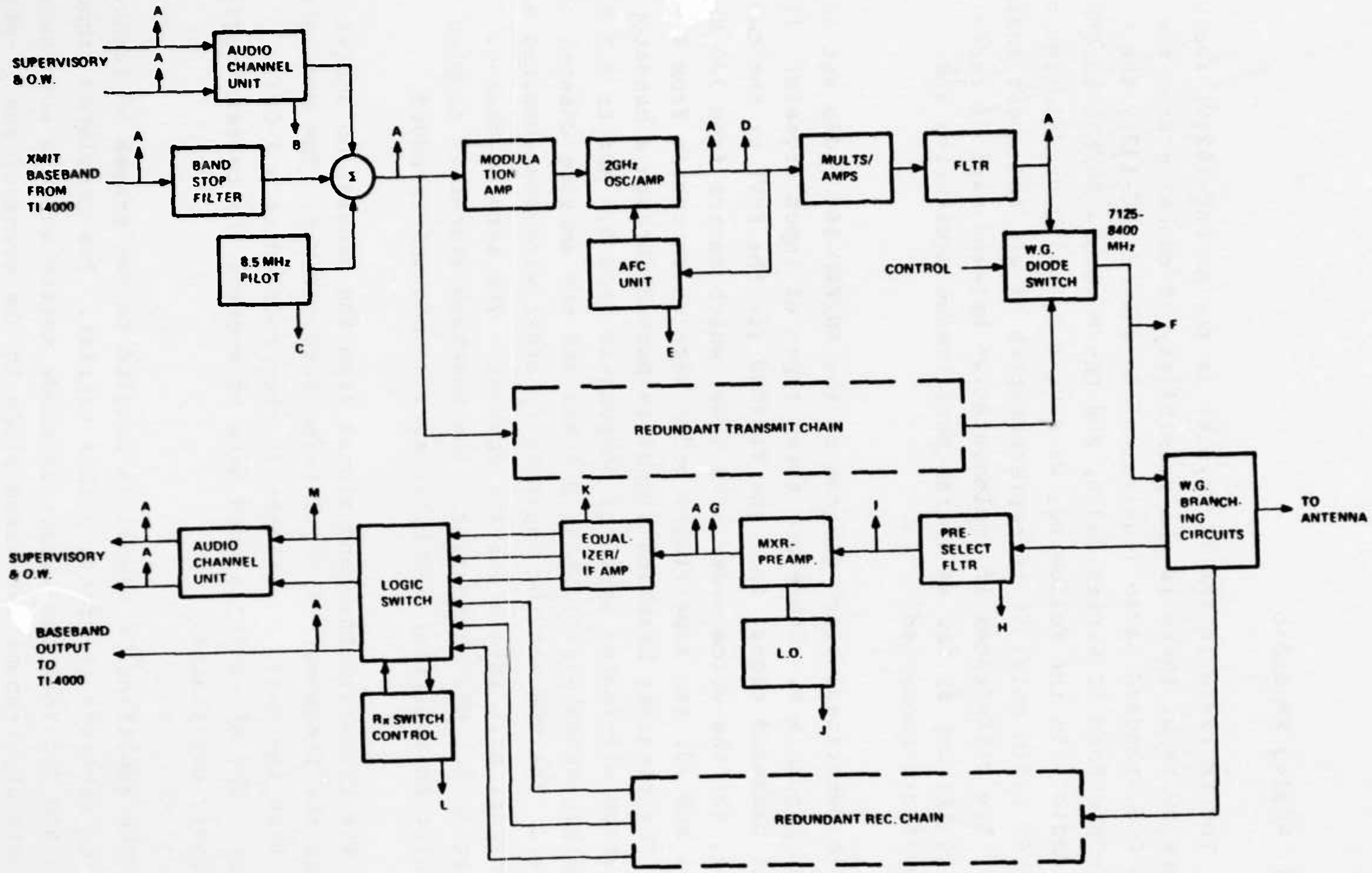


Figure A-8. AN/FRC-162 Functional Block Diagram

At the receiver, the received signal is passed through a preselection filter and coupled to the mixer/preamplifier module, where the input signal is mixed with a local oscillator signal to generate an IF signal and the IF signal is amplified in the preamplifier. The signal is then equalized to compensate for phase distortion in the radio set, waveguide and antenna, coupled to the IF antenna, and coupled to the IF amplifier. The IF amplifier amplifies, limits and demodulates the IF signal to recover the composite baseband signal.

The demodulated signals from two redundant receivers are coupled to the sensor switch unit which selects one of them. The selected signal is then split into two channels. One channel provides the transmitted baseband output. The other is FM-demodulated to recover the service channel. The service channel is further split into the VOW and the supervisory order wire in the audio channel unit.

The alarms and test points shown in Table A-12 are typically provided for the purpose of performance monitoring and assessment. They are also indicated in Figure A-8.

A.5.2.2 DAU

A detailed functional block diagram of the DAU is shown in Figure A-9. Depending on the particular schemes for its implementation, the diagram should be modified slightly. However, the basic functional performance monitoring and assessment requirements will remain unchanged.

At the DAU transmit section, up to two mission bit streams and a single service-channel bit stream, each with associated timing, are synchronously time-division-multiplexed. The MBS and SCBS port ratios are the same as for the DRAMA radio. The output of the internal multiplexer is randomized to eliminate discrete spectral components in the transmitted signal.

TABLE A-12. AN/FRC-162 MONITOR/TEST POINTS

BLOCK DIAG. REF.	MONITORED CONDITIONS/PARAMETERS
A	DATA INPUT/OUTPUT
B	FM SUBCARRIER LEVEL
C	PILOT OSCILLATOR
D	T_x PILOT LEVEL
E	T_x AFC VOLTAGE
F	T_x RF POWER OUTPUT
G	R_x SQUELCH
H	R_x AGC VOLTAGE
I	RECEIVED NOISE
J	R_x PHASE LOCK
K	RECEIVED PILOT LEVEL
L	RECEIVE SWITCH CONTROL UNIT
M	R_x SUBCARRIER LEVEL

IN ADDITION, ALARMS FOR PRIMARY POWER, ANCILLARY POWER SUPPLIES AND T_x/R_x POWER SUPPLIES.

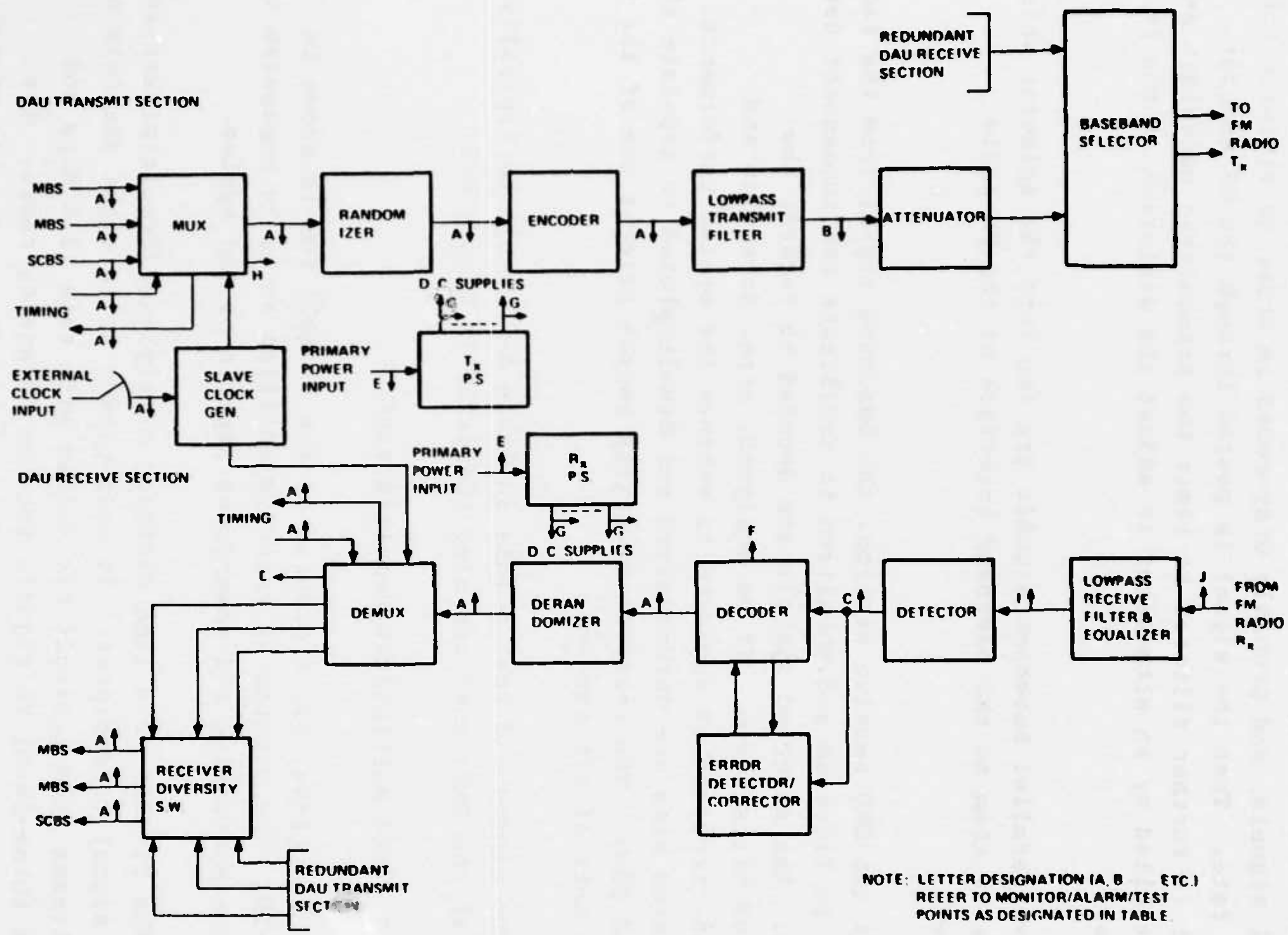


Figure A-9. Digital Applique Unit (DAU) Block Diagram

At the encoder, the random binary inputs are converted into multilevel signals, and probably Gray-coded in order to minimize the bit-error rate. Then the signal is passed through the PR encoder. The signal is further filtered to limit the transmitted bandwidth and level-controlled by an attenuator to adjust the deviation in the FM transmitter.

Two parallel baseband signals are fed into the selector which passes one of them to the baseband interface of the FM radio transmitter.

At the DAU receive section, the baseband signal from the radio interface is filtered and equalized to facilitate the subsequent data detection. The detected symbols are decoded to recover the transmitted bit streams. If so designed, error detection and correction circuitry is employed to enhance the system performance. The recovered bits are derandomized and demultiplexed to separate the MBS(s) and SCBS. The receiver diversity switch selects one of the two redundant sets of bit streams.

The alarms and test points in Table A-13 would be typically provided at the DAU; they are also indicated in Figure A-9.

A.5.2.3 T1-4000 Multiplexer/Demultiplexer

A functional block diagram of the T1-4000 TDM is shown in Figure A-10. The diagram is rather simplified so as to emphasize the performance monitoring and assessment aspects of the system.

The T1-4000 is a time division multiplexer/demultiplexer and baseband signal conditioner. It multiplexes up to eight channels of T1 bit streams into a single bit stream with rate 12.6 Mbps and generates three-level PR signals for the FM analog radio. The multiplexer is asynchronous in the sense that the input bit streams

TABLE A-13. DAU TYPICAL CPMAS MONITOR/TEST POINTS

BLOCK DIAGRAM REFERENCE	MONITORED CONDITION/PARAMETER	REMARKS
A	DATA INPUT/OUTPUT	MONITORED FOR LOSS OF DATA OR TIMING.
B	MODULATOR OUTPUT	MONITORED FOR LOSS OF DATA ACTIVITY.
C	DEMODULATOR OUTPUT	MONITORED FOR LOSS OF ACTIVITY.
D	FRAME	DEMULTIPLEXER MONITORED FOR LOSS OF RECEIVE FRAME SYNCHRONIZATION
E	POWER SUPPLY	A VISUAL INDICATOR PROVIDED TO INDICATE PRIMARY AC OR DC POWER HAS BEEN APPLIED.
F	ERROR THRESHOLD	AN ALARM PROVIDED TO INDICATE WHEN THE ERROR RATE EXCEEDS THRESHOLD.
G	DC VOLTAGES AND CURRENTS	A METHOD TO MEASURE DC POWER VOLTAGES AND CURRENTS

TABLE A-13. DAU TYPICAL CPMAS MONITOR/TEST POINTS (CONT)

DAU TYPICAL CPMAS MONITOR/TEST (CONT.)

BLOCK DIAGRAM REFERENCE	MONITORED CONDITION/PARAMETER	REMARKS
H	FRAMING ERRORS	TEST POINTS TO MONITOR FRAMING ERRORS.
I	SIGNAL QUALITY MONITOR	A TEST POINT TO MONITOR DEGRADATION OF THE RECEIVED DEMODULATED SIGNAL (EYE PATTERN) PRIOR TO DATA RECOVERY AND AN OUTPUT VOLTAGE THAT IS MONOTONICALLY RELATED TO THE SIGNAL-TO-NOISE RATIO OF THE DEMODULATED SIGNAL.
J	OUT-OF-BAND NOISE MONITOR	A METER TO DISPLAY A SIGNAL WHICH IS PROPORTIONAL TO THE MAGNITUDE OF THE OUT-OF-BAND BASEBAND NOISE.
–	LOSS OF ACTIVITY	ALARMS FOR ALL MODULE OUTPUT.
–	EQUIPMENT STATUS	INDICATORS FOR EACH DAU RECEIVER, TRANSMITTER AND POWER SUPPLY AND THE DIVERSITY SWITCH STATUS.

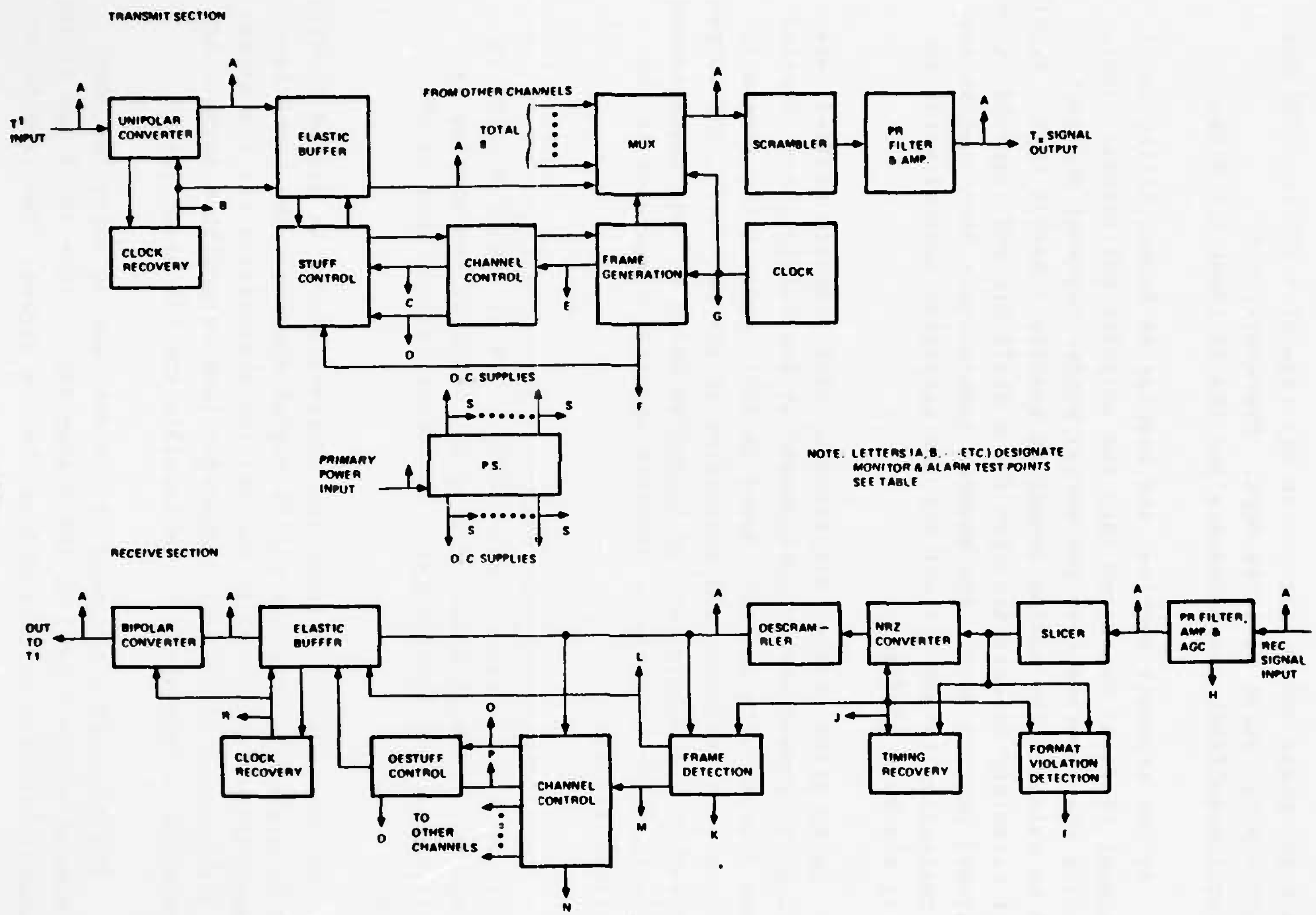


Figure A-10. T1-4000 Multiplexer Block Diagram

may have any phase and variations in bit rate of + 150 to - 300 Bps from the nominal value of 1.544 Mbps. Therefore, bit stuffings/destuffings are necessary for the T1 input bit streams.

At the transmit section, the bipolar RZ format of the input data signal is first converted into the unipolar NRZ format. Then, stuff bits are inserted into the serial buffer register whenever needed to maintain the buffer output at exactly 1.544935 Mbps. Stuff control circuitry detects the need for a stuff bit and requests it to the channel control unit. The channel control unit then enables the stuff controller to add a stuff bit and generates control words to identify the bits stuffed.

Up to eight channel bit streams, each properly stuffed, are synchronously time-division multiplexed at the multiplexer. Control bits and framing bits are also added to the composite bit stream to facilitate demultiplexing and destuffing at the receiver. The output bit stream of the multiplexer is scrambled using a 7-bit pseudorandom sequence in order to minimize discrete spectral components in the transmitted signal.

The scrambled NRZ data signal is then converted into a duobinary PR signal before transmission. The PR signal shaping is performed by frequency-domain filtering. Half of the shaping is accomplished at the transmitter. The other half is done at the receiver.

At the receive section, the received signal is passed through a receive filter to complete the PR signal shaping. The three-level duobinary signal is sliced to recover the transmitted NRZ bit stream. Since a duobinary signal has a specific level-transition format, any violation can be monitored to extrapolate the bit error rate.

The detected bit stream is now descrambled using the same pseudorandom sequence used at the transmitter. Then the frame timing and control bits are recovered from the bit stream. The framing and

control recovery units provide control signals to eliminate the stuff bits added at the transmitter. Finally, the destuffed channel bit stream is converted into the bipolar RZ signal.

The alarms and test points shown in Table A-14 are provided at the T1-4000 for the purpose of performance monitoring and assessment. They are also indicated in Figure A-10.

A.6 Group Data Modem (AN/USC-26)

The Group Data Modem (GDM) is used to convert a group-rate digital bit stream into a 60 to 108 KHz signal that can be frequency-division-multiplexed with other group signals and then transmitted over the existing FM equipment. In addition to the standard modulator output bandwidth of 60-108 KHz, the capability exists for providing a modulated output which occupies one-half of the available group bandwidth. The AN/USC-26 can be interfaced with TDM set AN/GSC-24, Communications Security Equipment such as the TSEC/KG-13, and certain computer and facsimile equipment. Figure A-11 is the block diagram of the GDM.

A.6.1 Data Rates

The GDM accepts binary NRZ serial data and timing at the modulator and transmits at rates of 19.2, 38.4, 50.0, 76.0, 115.2, and 153.6 Kb/s. The GDM can transmit in the Half Group mode only at the data rates 19.2, 38.4, 50.0, and 76.8 Kb/s.

A.6.2 Alarms

The performance monitoring and alarm unit located within the GDM provides normal and alarm function status indicators which are remotable up to 1000 feet. The alarm and performance monitor signals are:

TABLE A-14. T1-4000 MONITOR/TEST POINTS

BLOCK DIAG. REF.	MONITORED CONDITION/PARAMETER
A	DATA INPUT/OUTPUT
B	T_x T1-RATE DERIVED CLOCK
C	STUFF ENABLE
D	STUFF TIME
E	CHANNEL CLOCK
F	BUFFER READ CLOCK
G	T_x CLOCK
H	AGC CONTROL SIGNAL
I	PR FORMAT VIOLATION ERRORS
J	RECEIVER DERIVED CLOCK
K	MAIN FRAMING BIT ERROR
L	BUFFER WRITE CLOCK
M	MAIN FRAME TIMING
N	CONTROL FRAME MARKER ERRORS
O	DESTUFF ENABLE
P	DESTUFF TIMING
Q	BUFFER OVERFLOW/UNDERFLOW
R	R_x T1-RATE DERIVED CLOCK
S	D. C. POWER SUPPLIES

IN ADDITION, ALARMS FOR LOOP, FUSE, MULTIPLEXER AND TRANSFER STATUS ARE PROVIDED.

AD-A047 207 GTE SYLVANIA INC NEEDHAM HEIGHTS MASS ELECTRONIC SYS--ETC F/G 9/6
AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL--ETC(U)
OCT 77 F30602-76-C-0433

UNCLASSIFIED RADC-TR-77-327 NL

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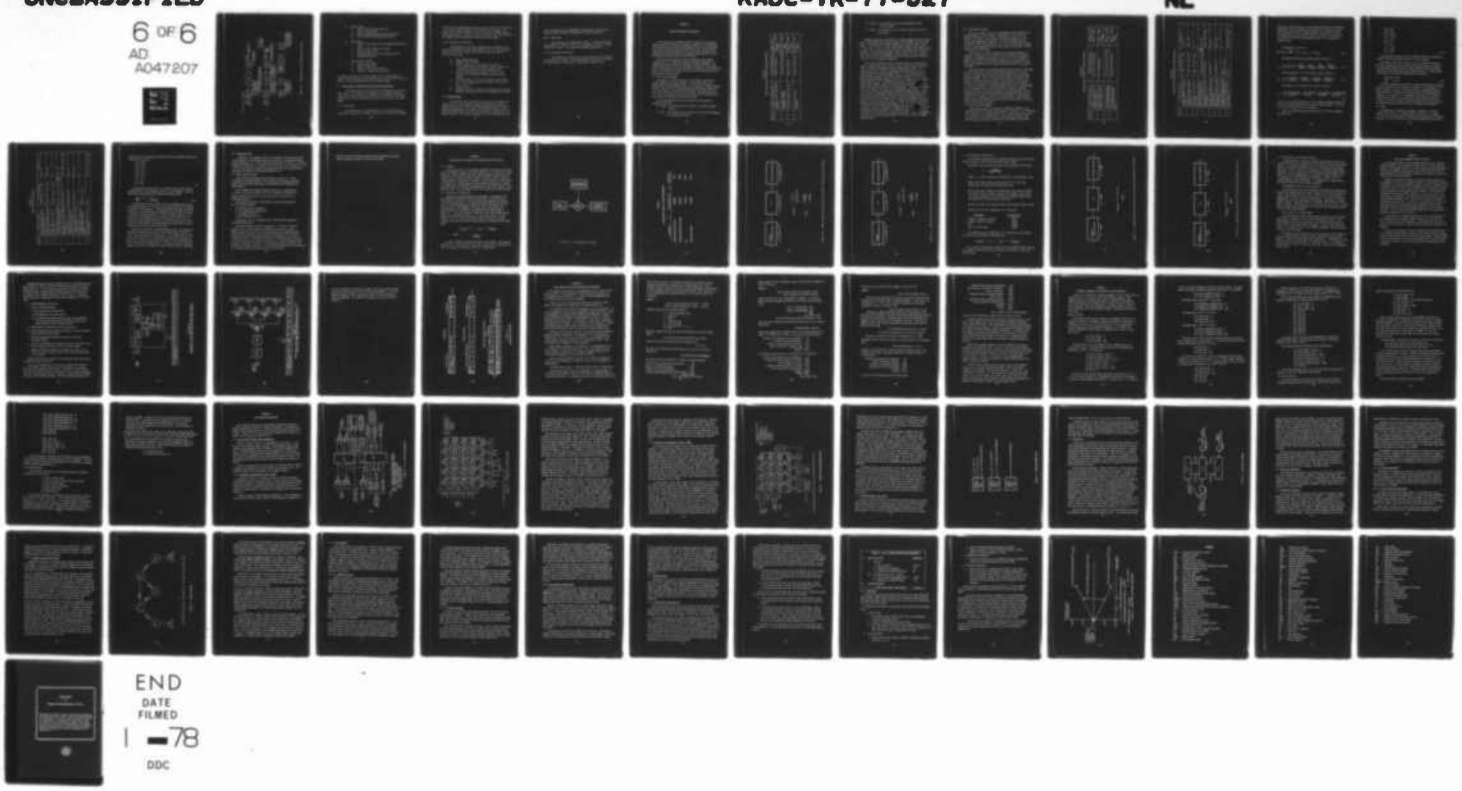

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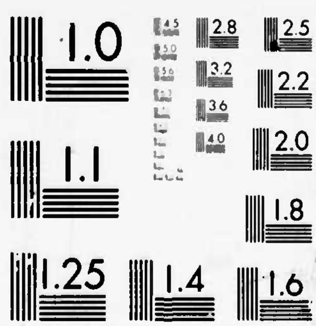


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

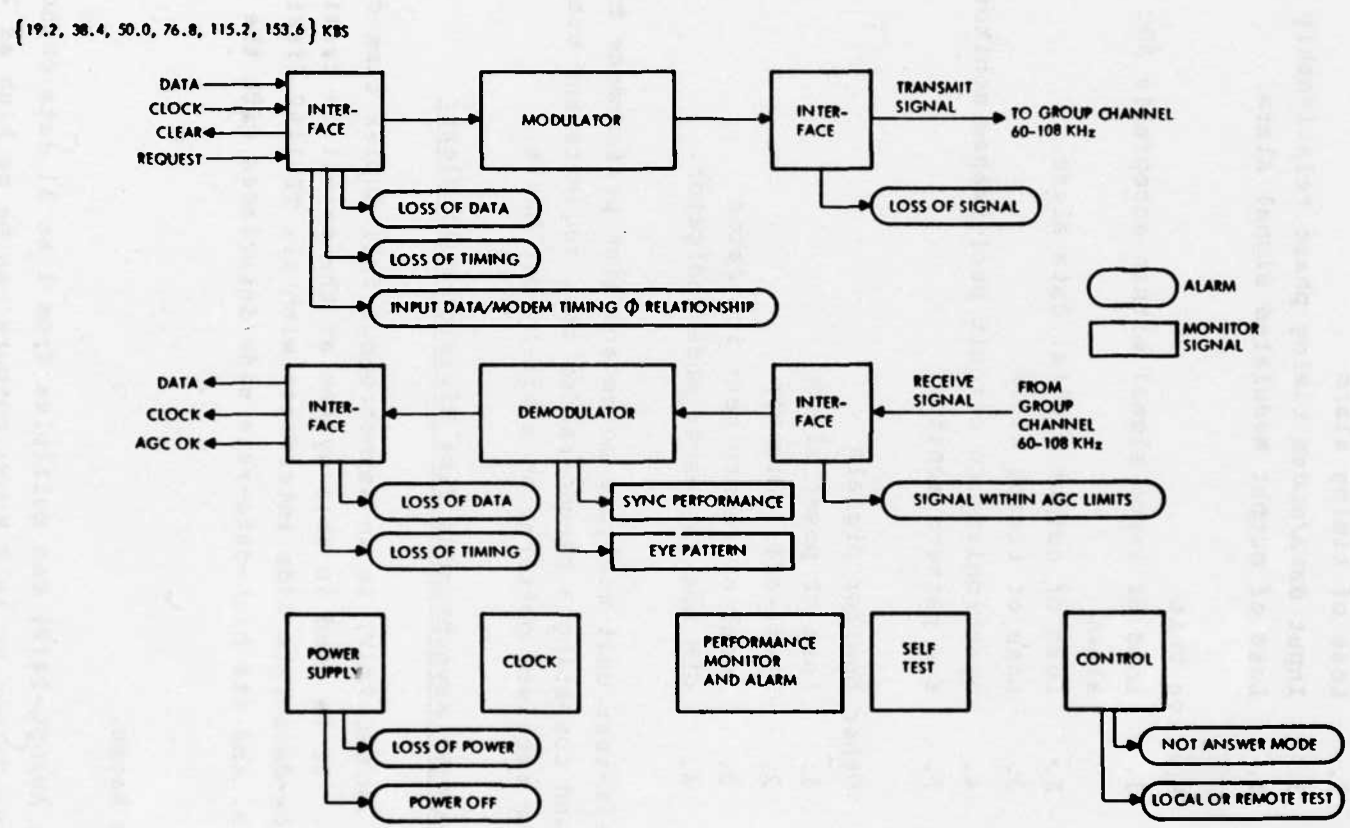


Figure A-11. AN/USC-26 Group Data Modem Block Diagram

a. Transmit Unit
   1. Loss of input digital data alarm
   2. Loss of timing alarm
   3. Input data/modem timing phase relationship
   4. Loss of output modulated signal alarm.

b. Receive Unit
   1. Loss of input signal within acceptable AGC limits alarm
   2. Loss of output digital data alarm
   3. Loss of timing alarm
   4. Synchronization circuit performance monitor
   5. Eye pattern monitor.

c. Other Monitor Signals
   1. Loss of power alarm
   2. Power-off indicator
   3. Local or remote test indicator
   4. GDM not in answer mode indicator.

The modem self-test unit monitors modem and link performance by generating and comparing a pseudo-random test sequence and outputting errors in the received pattern, on a bit-by-bit basis.

A.7 AN/GSC-24(V) Asynchronous Time Division Multiplexer

The AN/GSC-24(V) is an asynchronous full-duplex time-division multiplexer. It is used in this system at the satellite terminal, where its low-data-rate side interfaces with six TD-1192 first level multiplexers, and its high-data-rate side interfaces with the MD920 modem.

A.7.1 Data Rates.

The AN/GSC-24(V) can multiplex from 1 to 31 data channels. Inputs can be 75 bps up to 3 Mbps; outputs can be as high as 10 Mbps.

By selecting or synthesizing the port rate, the output can be matched to the output family required by the AN/FRC-163 or the DAU. The output rate can be increased to 12.672 to match the highest input to the AN/FRC-163 radio or the FM radio with the DAU. The input card for the AN/GSC-24 can be modified to accept up to 6.176 Mbps.

A.7.2 Diagnostics and Alarms.

The AN/GSC-24(V) has built-in diagnostics and alarms, and a modular construction to aid in maintenance. The unit has front panel visual indicators and remote alarm closures which will show the following conditions:

a) Power supply energized
b) Tripped circuit breaker
c) Loss of frame alarm; two alarms, one which is extinguished when the multiplexer regains frame, and another which remains ON until manually reset
d) Out-of-tolerance alarm; modulator loses bit count integrity on any channel; separate alarm for each channel
e) Overhead channel bit error rate alarm; demultiplexer error rate exceeds selectable threshold, may be 10^{-4}, 10^{-3}, 10^{-2} or 10^{-1}
f) Thermal alarm
g) Diagnostic alarms; indicate an equipment fault has been detected, and which portion of the equipment has failed.

A.8 MD-920/G Modem.

The MD-920/G Modem is used for interfacing and transmitting digital traffic over the Defense Satellite Communications System (DSCS) during the phase when both analog and digital traffic must be handled simultaneously. The modem is a 70 MHz IF biphase Coherent Phase Shift Keying Unit with both send and receive functions for full duplex operation. Differential coding, error correcting coding, and

data rate selection are independently selectable on transmit and receive sides to provide the capability of nodal operation.

A.8.1 Data Rates.

The modem has an any-data-rate design. It can accept rates from 16 Kb/s to 10 Mb/s, $C \times 75 \times 2^N$, 1.544 Mb/s, 50 kb/s, 1.8 Mb/s, 16 Kb/s and 32 Kb/s. The rates are thumbwheel-selectable.

A.8.2 Performance Monitoring.

The modem has a pseudo error rate detector, with a threshold of 50 percent full scale. The average number of failures in a block of bits received is displayed on the modem front-panel meter.

APPENDIX B

CPMAS EFFECTIVENESS CALCULATIONS

In this appendix the methodology used to evaluate the digroup and data/VF channel unavailabilities presented in Section 4.2 are discussed. The method involves calculating the unavailabilities for each equipment composing the reference digroup and data VF circuits, calculating the propagation media unavailability, and combining these results to obtain the digroup and data/VF circuit unavailabilities.

The assumptions required for these calculations can be broadly categorized as: (1) assumptions based upon equipment complexity, (2) assumptions based upon BITE fault monitoring, and (3) estimates of the failure outage times for the various CPMAS configurations. The assumptions made in this appendix are based in part upon the KG-81 specification and DRAMA equipment specifications.

B.1 First Level Multiplexer

The DRAMA first level multiplexer is non-redundant consisting of channel equipment and common equipment. Four failure types can be identified as unalarmed/alarmed failures in the channel or common equipment. Table B-1 shows the first level multiplexer failure analysis, where the four failure types are identified and described. The probability that a first level multiplexer failure will be a certain type is presented as is the outage time associated with each failure type.

The failure probability for each of the four failure types is evaluated in terms of:

a) P(COM) - the probability that a failure is a common equipment failure.

b) P(CH) - the probability that a failure is in the channel equipment for a particular channel.

TABLE B-1

FIRST LEVEL MULTIPLEXER FAILURE ANALYSIS

Failure	Failure Description	Failure Probability	Outage Time
1	Alarmed Common Equipment Failure	$P(COM) \bullet P(COM\ A)$	$MTTR_{COM} + MTTI + MCT_{DG}$
2	Unalarmed Common Equipment Failure	$P(COM) \bullet \left[1-P(COM\ A)\right]$	$MTTR_{COM} + MTTI + MCT_{DG}$
3	Alarmed Channel Failure	$P(CH) \bullet P(CH\ A)$	$MTTR_{CH} + MTTI + MCT_{CH}$
4	Unalarmed Channel Failure	$P(CH) \bullet \left[1-P(CH\ A)\right]$	$MTTR_{CH} + MTTI + MCT_{CH}$

c) P(COM A) - the probability that a common equipment failure will be alarmed.

d) P(CH A) - the probability that a channel equipment failure will be alarmed.

Indications are that the complexity of common equipment should be nearly equal to the complexity of channel equipment for the DRAMA first level multiplexer. Since there are 24 channel inputs per multiplexer, then P (COM) = 0.5 and P (CH) = 0.5/24 = 0.0208. DCEC technical report 12/76 indicates that at least 75% of all failures affecting two or more channels shall be alarmed. Therefore, a concervative assumption is that P (COM) A) = 0.75. Furthermore, very few first level multiplexer channel failures will be alarmed and P (CH A) = 0.1 is a realistic assumption.

The outage time associated with each failure type can be expressed in terms of equipment mean-time -to-repair (MITR), CPMAS mean-time-to-isolate (MITI) a failure, and maintenance mean-coordination-time (MCT). The equipment mean time to repair is dependent upon whether the failure is a common equipment or channel equipment failure. First level multiplexer specifications (DRAMA) indicate that the MITR is fifteen (15) minutes for common equipment failures ($MITR_{COM}$) and five (5) minutes for channel equipment failures ($MITR_{CH}$). The mean time to isolate a failure (MITI) is dependent upon whether a manual or an automatic fault detection/isolation procedure is enployed (see section 6 of this appendix). The mean coordination time is the average time required to coordinate equipment repair. Due to the logistics of coordinating between sites and the greater urgency of repairing digroup and supergroup failures, the mean coordination time for channel failures will be greater than for digroup and supergroup failures. Channel mean coodination times (MCT_{CH}) of twenty (20) minutes and di-group/supergroup mean coordination times MCT_{DG}) of ten (10) minutes should be realistic in light of DCS network configurations and policies. First level multiplexers have been assumed to be located at manned sites and as such travel time is not a factor in a failure outage time. The mean-time-between failures for the first level multiplexer is 3500 hours (based upon DRAMA specifications).

B.2 Crypto/Crypto By-Pass

The trunk encryption device is non-redundant with the capability of being by-passed in case of failure. Additionally, a failure can be alarmed or unalarmed. This equipment configuration leads to the four failure types indicated in Table B-2. The failure probabilities are expressed in terms of the probability of a failure being alarmed, denoted as P(A), and the probability of the crypto by-pass failing prior to being used, denoted by P(By-Fails).

Since failure of a trunk encryption device affects more than two channels, then (per TR 12-76) at least 75% of failures will be alarmed, therefore, a conservative assumption is that P (A) = 0.75. Based on a MTBF of 120,000 hours for the crypto by-pass and a KG-81 MTBF of 10,000 hours, the probability that the crypto by-pass fails prior to being used is 0.7996.

The outage times for the trunk encryption device is given in Table B-2 and can be expressed in terms of mean-time-to-isolate MTTI a failure, mean-time-to-repair MTTR a failure, mean coordination time MCT, and mean by-pass time MBPT. A MTTR of 30 minutes and a MTBF of 10,000 hours were assumed. As mentioned in the Section 1 of this appendix, a MCT of ten (10 minutes) was used because a Crypto/Crypto by-pass failure results in the loss of a supergroup. The MBPT was assumed to be one (1) minutes based upon the assumption that the nodal controller is capable of remotely acrivating the by-pass from the nodal control terminal position. MTTI is dependent upon the use of automatic/manual fault detection/isolation procedures and is discussed in Section 6 of this appendix. Bulk encryption devices were assumed located at manned facilities, and therefore, no travel time is required for their repair.

B.3 Second Level Multiplexer

The DRAMA second level multiplexer is completely redundant. This redundancy leads to faults being categorized as in Table B-3. The probability that a failure is of a certain type is given in this table where P_C and P_P are, respectively, the probability of a failure being a common or port failure; and P_{CA} and P_{PA} are, respectively, the probability that these

TABLE B-2

CRYPTO/CRYPTO BY-PASS FAILURE ANALYSIS

Failure	Failure Description	Failure Probability	Outage Time
1	Alarmed Crypto Failure, Crypto By-Passed	$P(A) \bullet [1-P(\text{BY-FAILS})]$	$MTTI_A + MBPT$
2	Alarmed Crypto Failure, Crypto By-Pass Fails	$P(A) \bullet P(\text{BY-FAILS})$	$MTTI_A + MTTR + MCT_{DG}$
3	Unalarmed Crypto Failure, Crypto By-Passed	$[1-P(A)] \bullet [1-P(\text{BY-FAILS})]$	$MTTI_{UA} + MBPT$
4	Unalarmed Crypto Failure, Crypto By-Pass Fails	$[1-P(A)] \bullet P(\text{BY-FAILS})$	$MTTI_{UA} + MTTR + MCT_{DG}$

TABLE B-3

SECOND LEVEL MULTIPLEXER FAILURE ANALYSIS

Failure	Failure description	Failure Probability	Outage Time
1	Alarmed common/port failure of on-line MUX, standby automatically switched in.	$1/2\left[P_C \cdot P_{CA} + P_P \cdot P_{PA}\right]$	$T_{SW} + T_D$
2	Unalarmed common/port failure of on-line MUX, standby manually switched in	$1/2\left[P_C\ (1-P_{CA})+P_P(1-P_{PA})\right]$	MTTI + MST
3	Alarmed common/port failure of standby MUX.	$1/2\left[P_C \cdot P_{CA} + P_P \cdot P_{PA}\right]$	O
4	Alarmed common/port failure(s) of standby MUX, switched on-line prior to on-line MUX failure	$1/2\left[P_C(1-P_{CA})+P_P(1-P_{PA})\right] e^{\frac{T/MTBF}{Q}}$	MTTI + MST
5	Common/port failure(s) of on-line and standby MUX, repair of one MUX required	See Equation B-2	$MTTR + MTTI + MCT_{DG}$
6	Common/port failure(s) of on-line and standby MUX, automatic switch restores service	See Equation B-3	$T_{SW} + T_D$
7	Common/port failure(s) of on-line and standby MUX, manual switch-in restores service	See Equation B-4	MTTI + MST
8	Unalarmed common/port failure(s) on standby MUX followed by alarmed common/port standby failure	$\frac{1-Q}{2Q}\left[P_C P_{CA} + P_P P_{PA}\right]$	O
9	Non-redundant equipment failure, repair required.	P_{NR} / Q	$MTTR + MTTI + MCT_{DG}$

failures are alarmed resulting in an automatic switchover to the redundant multiplexer. Off-line equipment can be periodically switched on-line to detect unalarmed failures in standby equipment, the variable T of Table B-3 denotes how often this periodic switch is initiated. The probability of a failure being in the non-redundant portions of the multiplexer, is denoted by P_{NR}.

The parameter Q is given by

$$Q=1-1/2\left(1-e^{-\frac{T}{MTBF}}\right)\left[P_C\,(1-P_{CA})+P_P\,(1-P_{PA})\right] \tag{B-1}$$

The probability of a failure being a type 5 failure is

$$P_5=\frac{1-Q}{2}\left\{\frac{P_C+P_P}{Q}-\frac{P_CR_1T_1}{1-R_1+R_1Q}-\frac{P_CR_1T_1}{1-T_1+T_1Q}-\frac{P_PR_2T_2}{1-R_2+R_2Q}-\frac{P_PR_2T_2}{1-T_2+T_2Q}\right\} \tag{B-2}$$

and the probability of a failure being a type 6 failure is

$$P_6=\frac{1-Q}{2}\left\{\frac{P_CP_{CA}R_1T_1}{1-R_1+R_1Q}+\frac{P_CP_{CA}R_1T_1}{1-T_1+T_1Q}+\frac{P_PP_{PA}R_2T_2}{1-R_2+R_2Q}+\frac{P_PP_{PA}R_2T_2}{1-T_2+T_2Q}\right\} \tag{B-3}$$

The probability of a failure being a type 7 failure is

$$P_7=\frac{1-Q}{2}\left\{\frac{P_C(1-P_{CA})R_1T_1}{1-R_1+R_1Q}+\frac{P_C(1-P_{CA})R_1T_1}{1-T_1+T_1Q}+\frac{P_P(1-P_{PA})R_2T_2}{1-R_2+R_2Q}+\frac{P_P(1-P_{PA})R_2T_2}{1-T_2+T_2Q}\right\} \tag{B-4}$$

where T_1 is the relative complexity of the transmitter common equipment and R_1 is the relative complexity of the receiver common equipment. T_2 and R_2 are similarly defined for the port equipment.

Based upon DRAMA multiplexer specifications, the following parameter values were set:

$P_{CA} = 0.97$
$P_{PA} = 0.97$
$P_C = 0.3781$
$P_P = 0.0777$
$P_{NR} = 0.0$
$T_1 = 0.5$
$R_1 = 1-T_1$
$T_2 = 0.333$
$R_2 = 1-T_2$ (B-5)

The equipment switching time T is a CPMAS variable and the benefits of changing T will be discussed in Section 6 of this appendix.

The outage times given in Table B-3 are as a function of automatic switching time T_{SW} plus time to activate automatic switch T_D, mean-time-to-isolate MTTI a failure, mean switching time MST for remote swtiching, mean-time-to-repair MTTR, and mean coordination time MCT. From the DRAMA specifications, the following outage times are specified:

$T_{SW} + T_D = 100$ ms
MTTR = 15 min (B-6)

The MTTI is dependent upon the use of automatic/manual fault detection/isolation procedures and is discussed in Section 6 of this appendix. The MST was assumed to be one (1) minute based upon the assumption that the nodal controller is capable of remotely switching the on-line/redundant equipment. From Section 1 of this appendix a MCT of ten (10) minutes was assumed because failure of the second level multiplexer will result in at least the loss of a digroup. Based upon DRAMA specifications the mean-time-between-failures is 1600 hours for the second level multiplexer.

B.4 Radio

The DRAMA radio is completely redundant, resulting in failures as categorized in Table B-4. Comparing Tables B-3 and B-4 it is evident that the radio and second level multiplexer failure analyses are essentially identical. The only differences in the failure probabilities result from

TABLE B-4

RADIO FAILURE ANALYSIS

Failure	Failure Description	Failure Probability	Outage Time
1	Alarmed common/port failure of on-line radio, standby automatically switched in.	$1/2\left[P_C \cdot \left[P_{CA} + P_P \cdot P_{PA}\right]\right.$	$T_{SW} + T_D$
2	Unalarmed common/port failure of on-line radio, standby manually switched in.	$1/2\left[P_C(1-P_{CA}) + P_P(1-P_{PA})\right]$	MTTI + MST
3	Alarmed common/port failure of standby radio.	$1/2\left[P_C \cdot P_{CA} + P_P \cdot P_{PA}\right]$	0
4	Unalarmed common/port failure(s) of standby radio, switched on-line prior to on-line radio failure.	$1/2\left[P_C(1-P_{CA})+P_P(1-P_{PA})\right] e^{\frac{T}{MTBF}} / Q$	MTTI + MST
5	Common/port failure(s) of on-line and standby radio, repair of one radio required.	See Equation B-2	$MTTR + MTTI + MCT_{DG} + MTT$
6	Common/port failure(s) of on-line and standby radio, automatic switch restores service.	See Equation B-3	$T_{SW} + T_D$
7	Common/port failure(s) of on-line and standby radio, manual switch-in restores service.	See Equation B-4	MTTI + MST
8	Unalarmed common/port failure(s) on standby radio followed by alarmed common/port standby failure.	$\frac{1-Q}{2Q}\left[P_C P_{CA} + P_P P_{PA}\right]$	0
9	Non-redundant equipment failure, repair required.	P_{NR} / Q	$MTTR + MTTI + MCT_{DG} + MTT$

variable values as furnished by government sources and DRAMA specifications. These are for the radio:

$$
\begin{aligned}
P_{CA} &= 0.98 \\
P_{PA} &= 0.97 \\
P_{C} &= 0.90 \\
P_{P} &= 0.03 \\
P_{NR} &= 0.01 \\
T_1 &= 0.5 \\
T_2 &= 0.5 \\
R_2 &= 1-T_2 \\
R_1 &= 1-T_1
\end{aligned}
\tag{B-7}
$$

The equipment switch-in time T is a CPMAS variable and the benefits of changing T will be discussed in Section 6 of this appendix. From the DRAMA radio specifications, the outage time parameters are:

$$
\begin{aligned}
T_{SW} + T_D &= 1 \text{ ms.} \\
\text{MTTR} &= 30 \text{ minutes}
\end{aligned}
\tag{B-8}
$$

The mean-time-to-isolate (MTTI) a failure is dependent upon the use of automatic/manual fault detection/isolation procedures and is discussed in Section 6 of this appendix. The mean switching time (MST) was assumed to be one (1) minute based upon the assumption that the nodal controller is capable of remotely switching the on-line/redundant equipment. From Section 1 of this appendix a mean coordination time (MCT) of ten (10) minutes was assumed because failure of the radio will result in at least the loss of a supergroup. Based upon DRAMA specifications the mean-time-between failures is 1600 hours for the radio.

Radios can be located at unattended repeater sites. The outage time associated with repair of the radio at unattended repeater sites must reflect the travel time to the remote site. It is assumed (per TR 12-76) that repair personnel are, on the average, located within 2-1/2 hours of these sites. Thus, the mean travel time (MTT) is zero for attended sites and 2-1/2 hours for unattended sites. The digroup availability analysis presented in Section 4 assumed that the two repeater sites are unattended.

B.5 Propagation Media

In addition to the equipment failures as discussed in the previous section of this appendix, the propagation media also contributes to digroup and data/VF channel unavailabilities. For the calculations presented in Section 4, the nominal propagation availability of 0.9999965 per link was used. This availability is for a 30 mile space diversity system over average terrain and is the average media availability considered in DCEC Technical Report 12-76.

B.6 CPMAS Related Variables

Several CPMAS configurations were evaluated in Section 4.2. These configurations considered manual versus automatic fault detection/isolation, second level multiplexer assessment, manned/unmanned radio assessment, and trend analysis.

For the CPMAS effectiveness analysis of Section 4.2, the mean time to isolate a failure was assumed to be five (5) minutes for manual fault detection/isolation and two (2) minutes (per BLRD) for automatic fault detection/isolations.

The digroup availability was evaluated by finding the availability of the following equipment:

- Two second level multiplexers
- Two crypto/crypto by-pass units
- Two manned radio sets
- Four unmanned radio sets.

In addition, three (3) propagation media effects must be included in the digroup availability.

The data/VF channel availability consists of: four Type A reference digroups, each of which contains the equipment listed above, one Type B reference digroup, and two first level multiplexers and two submultiplexers. Since the Type B reference digroup contains a troproscatter link, for which availability data is not available, the specified availability (per TR 12-76) of 0.9997 was used for the results of Section 4.2. The first level multiplexer information presented in Section 1 of this appendix assumed a VF channel input. The results presented in Section 4.2 for data channels assumed that the complexity of the channel equipment is equal to that of the VF channel.

Section 4.2 for data channels assumed that the complexity of the data channel equipment is equal to that of the VF channel.

APPENDIX C

RELIABILITY/AVAILABILITY/MAINTAINABILITY ANALYSIS

C.1 Summary

The RAM analysis of the CPMAS equipment consisted of a parts count reliability prediction and construction of functional block diagrams. Math models were developed and quantified using estimated failure rates and repair times to derive overall reliability/availability prediction results. This process is illustrated in Figure C-1. Additionally, a preliminary maintenance concept was established to define organizational level (OL) repair, intermediate level (IL) and depot level (DL) maintenance requirements.

C.2 Reliability Prediction

Reliability predictions were prepared in accordance with MIL-HDBK-217B Parts Count Method and vendor supplied failure rates where available. A ground fixed environment was assumed for all calculations and B-2 quality level was chosen for I.C. calculations. The CPMAS-D, CIS, and control position were analyzed and the reliability predictions are summarized in Table C-1. For the purpose of modeling, the three CPMAS equipments were considered serial (i.e., any part failure in the CPMAS-D, CIS, or control position would constitute a system failure) with the following formula used to calculate the system MTBF:

$$\lambda_{system} = \lambda_D + \lambda_{CIS} + \lambda_{CONTROL}$$

$$MTBF = \frac{1}{\lambda_{system}}$$

System reliability block diagrams, math models, and summary results for a nodal station with eight radios and a repeater station are shown in Figure C-2 and C-3, respectively.

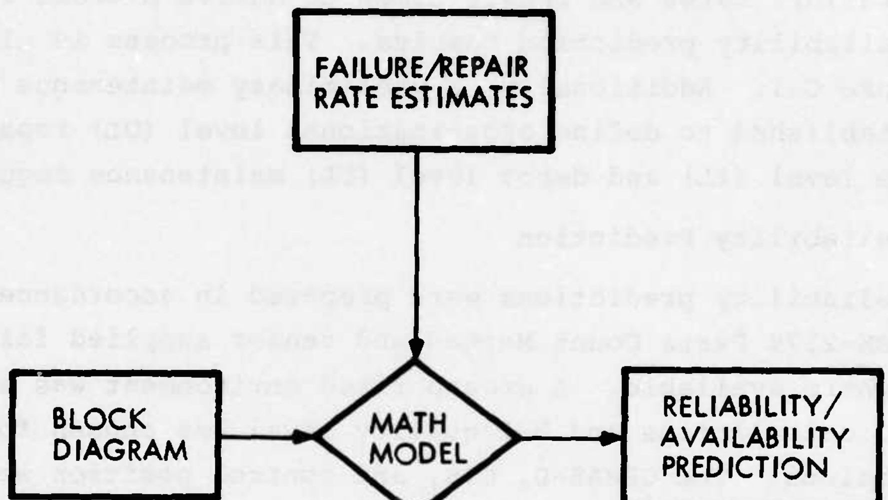
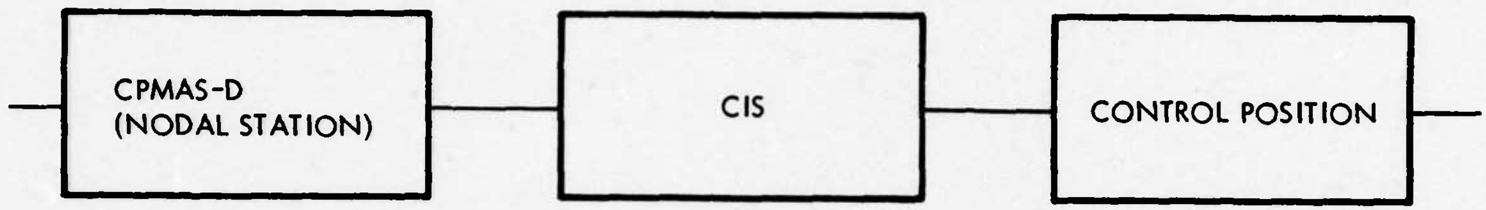


Figure C-1. RAM Analysis Process

TABLE C-1

EQUIPMENT RELIABILITY ANALYSIS SUMMARY

EQUIPMENT	FAILURE RATE 10^{-6}	MTBF (HRS.)
CPMAS-D (NODAL STATION)	839.0679	1192
CPMAS-D (REPEATER STATION)	281.0527	3558
CIS	93.3155	10716
CONTROL POSITION	440.5286	2270



$\lambda_1 = 839.0679 \times 10^{-6}$ $\lambda_2 = 93.3155 \times 10^{-6}$ $\lambda_3 = 440.5286 \times 10^{-6}$

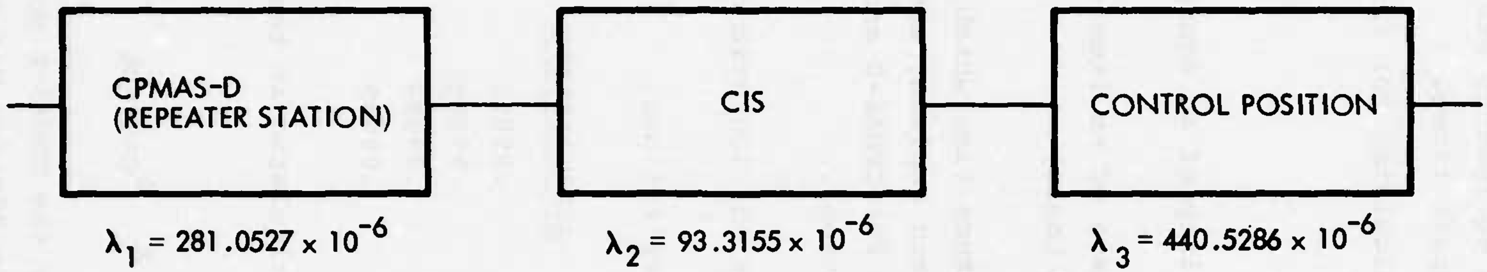
$$\lambda_{SYSTEM} = \lambda_1 + \lambda_2 + \lambda_3$$

$$= 1372.912 \times 10^{-6}$$

$$MTBF = \frac{1}{\lambda_{SYSTEM}}$$

$$= 728 \text{ HRS.}$$

Figure C-2. CPMAS System Reliability Block Diagram (Nodal Station/8 Radios)



$$\lambda_{SYSTEM} = \lambda_1 + \lambda_2 + \lambda_3$$

$$= 814.897 \times 10^{-6}$$

$$MTBF = \frac{1}{\lambda_{SYSTEM}}$$

$$= 1227 \text{ HRS}$$

Figure C-3. CPMAS System Realiability Block Diagram (Repeater Station)

C.3 Availability Prediction

The inherent availability of CPMAS equipments was calculated using reliability data and estimated repair times.

Equipment item availability was calculated for the formula:

$$A = \frac{MTBF}{MTBF + Mct}$$

where: A is the inherent availability of an equipment item

MTBF is the mean-time-between-failure of an item (the reciprocal of failures per million hours)

Mct is the mean corrective maintenance time which includes the time to fault isolate, remove and replace, and verify a failure (estimated at 10 minutes for CPMAS-D and CIS and 15 minutes for the controller position).

The Mct excludes all administrative and logistic delay times.

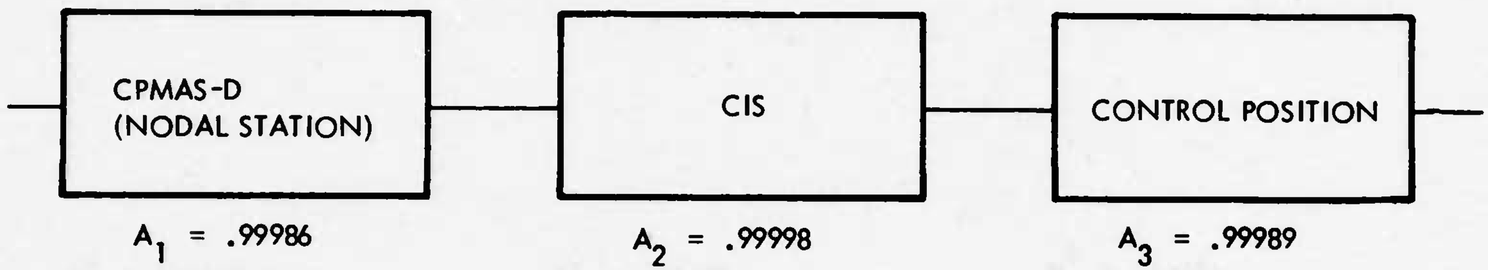
Availability of the equipments is as follows:

EQUIPMENT	AVAILABILITY
CPMAS-D (Repeater Station)	.99995
CPMAS-D (Nodal 8 Radios)	.99986
CIS	.99998
Station Controller	.99989

The CPMAS system availability is calculated as the product of individual equipment availabilities.

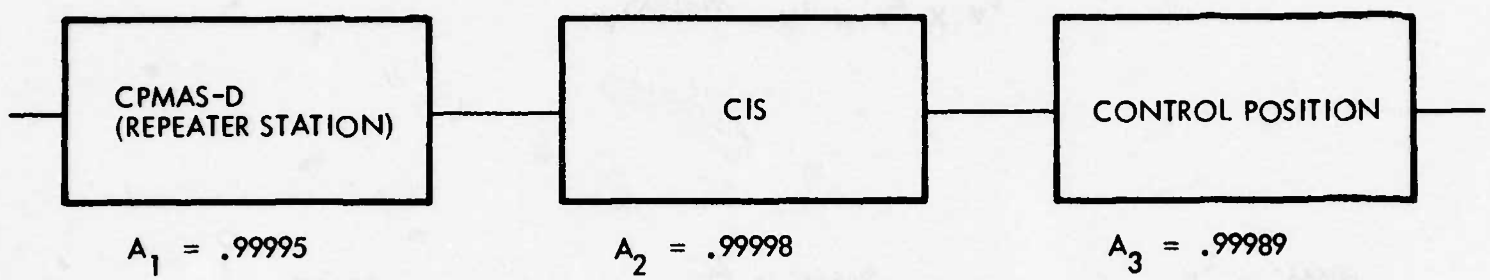
$$A_{SYSTEM} = A_D \times A_{CIS} \times A_{CONTROL}$$

The system availability results for the CPMAS-D Nodal station and CPMAS-D Repeater Station are shown in Figures C-4 and C-5, respectively.



$$A_{SYSTEM} = A_1 \times A_2 \times A_3$$
$$= .99973$$

Figure C-4. CPMAS System Availability Block Diagram (Nodal Station/8 Radios)



$$A_{SYSTEM} = A_1 \times A_2 \times A_3$$

$$= .99982$$

Figure C-5. CPMAS System Availability Block Diagram (Repeater Station)

C.4 Preliminary Maintenance Concept

OL Maintenance is that maintenance performed by operating and maintenance (O&M) personnel who are part of the using organization. The CPMAS equipment will be of modular design having self-test features and fault indicators to detect catastrophic failures. Fault isolation to the failed Line Replacement Units (LRU), will be accomplished via indicators either directly or in conjunction with diagnostic procedures. Repair will be accomplished by LRU replacement. A complement of ready spares will be provided with the CPMAS equipment.

Intermediate Level (IL) Maintenance

IL maintenance is that maintenance performed by maintenance activities responsible for direct support of the using organizations. The maintenance activity at this level will consist of replacement of panel mounted compartments. The repair of power modules will be by replacement of switches, connectors, wired-in PCB's, cables. Some PCB's will be repaired at this level. Intermediate maintenance personnel will also provide technical assistance to using organizations.

Depot Level (DL) Maintenance

DL maintenance is that maintenance performed by maintenance activities to support the two lower maintenance levels. The maintenance activity will consist of the testing and repair of plug-in PCB's and power supply modules. It will also cover the repair of internal wiring of the CPMAS equipment, which includes wirewrap and soldering.

In addition, this activity will be concerned in the rebuilding of damaged CPMAS equipment, which includes front and rear panels, connector plates and case replacement. A CPMAS PCB tester will be used for the checkout of repaired cards. An automatic tester will be used for the test and fault isolation of components on the PCB's.

APPENDIX D

NODAL AREA PARAMETER DATABASE STRUCUTRE

The structure imposed on the equipment parameters in the nodal area parameter database, will influence the efficiency of the fault analysis process. This appendix addresses, in brief, a method of structuring data so that related parameters are grouped for easy retrieval and the order of parameter groups in the database corresponds to the sequence in which they are utilized in the fault analysis.

Alarms and analog monitor signals available for fault analysis will be dependent on the specific equipment observed. Fault detection/isolation algorithms will be general enough to encompass any type of equipment, given a sufficient number of alarms are provided and the algorithms are supplied with the necessary characterization of the equipment. Digital Radio and Multiplexer Acquisition (DRAMA) equipments will be used as a basis for illustration of techniques. The anticipated alarms and monitor signals from the DRAMA equipments, KG-81 trunk encryption device and submux are indicated in other sections. In addition, it is expected that alarms for the operationof the power generation and distribution system, the RF distribution system, and the environmental conditions at a site will be provided. These alarms along with CPMAS outputs will form the minimum parameter database for fault analysis.

The database will be updated periodically as new alarm observations are received from the telemetry channels terminating at the node, as well as observations on the node itself. Processing of data for fault detection and isolation will require that some structure be imposed on the database.

Each piece of equipment or group of equipment will be characterized by an equipment status message consisting of all binary alarms, and binary encoded analog monitor values and counts of pulsed alarms. Status messages would be standardized for each distinct equipment type, and would include an equipment identifier code to define the type and configuration of the equipment.

Equipment messages together with CPMAS data and a site identifier would form a site word. The site identifier should serve to identify the equipments present at a site and uniquely identify the particular site within the entire system. Equipment status messages within the site word would be ordered by their relative importance to fault analysis. An ordering which would serve to emphasize more severe fault conditions first is given below.

1. CPMAS equipment status alarms.

2. Facility related equipments.

   i) Power generation and distribution.

   ii) Environmental and perimeter status.

   iii) RF distribution systems ordered by their link association. The first associated with the link nearest node and the others ordered as their clockwise location.

3. Radio parameters ordered by their link association.

4. Trunk encryption devices ordered in relation to the link and radio port to which they are attached.

5. 2nd Level multiplexers ordered the same way as the trunk encryption devices.

6. 1st Level multiplexers are ordered by the radio, the 2nd level mux, and the digroup output port to which they are attached.

7. Submux's would follow ordered by the radio, 2nd level mux, 1st level mux, and the channel I/O port on the 1st level mux to which it is attached.

Examples of ordering of equipment status messages within the site word are shown in Figures D-1 and D-2.

Site words corresponding to sites sharing a common service channel bit stream (SCBS) telemetry channel would be combined into a telemetry word with sites ordered by their proximity to the node. These site words along with information pertaining to equipment at the node would be combined to form the nodal parameter database. The nodal parameter database would

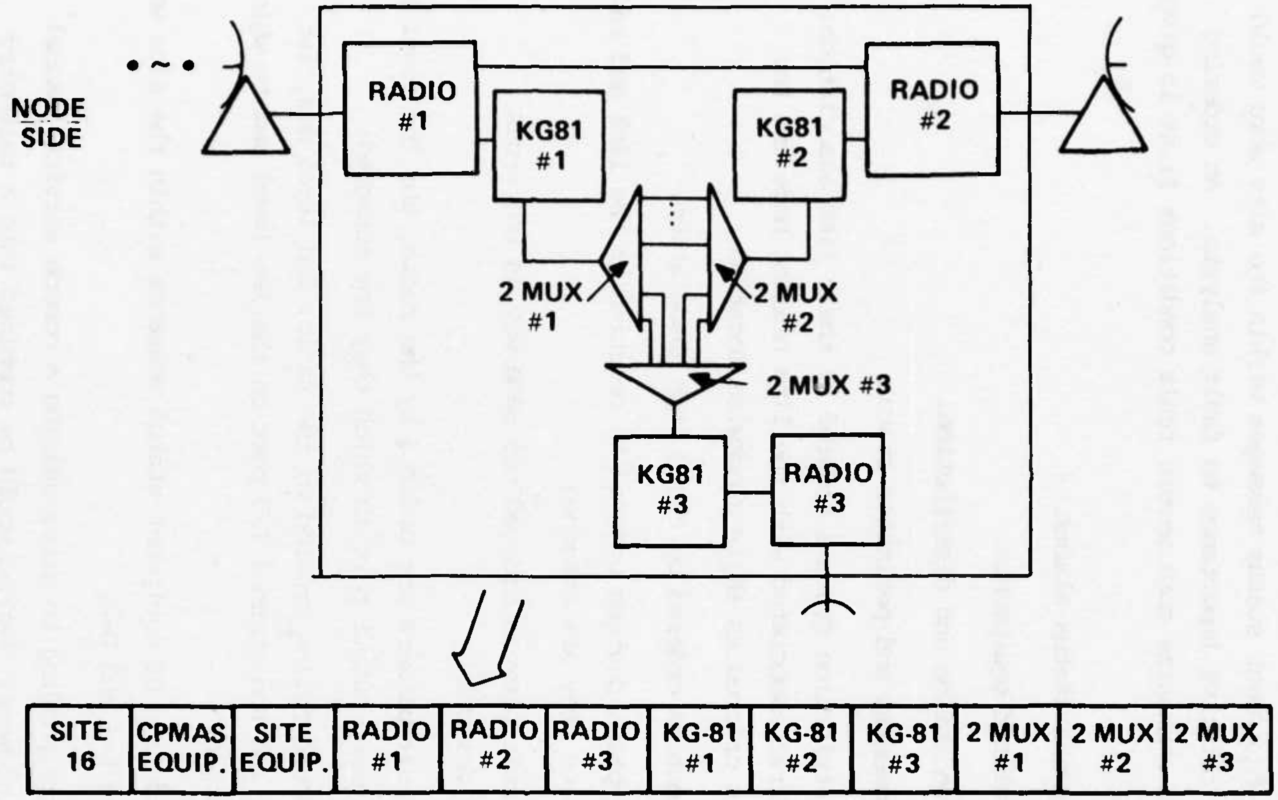


FIGURE D-1
RELATION OF EQUIPMENT STATUS MESSAGES WITHIN A SITE WORD FOR A BRANCHING REPEAT CONFIGURATION

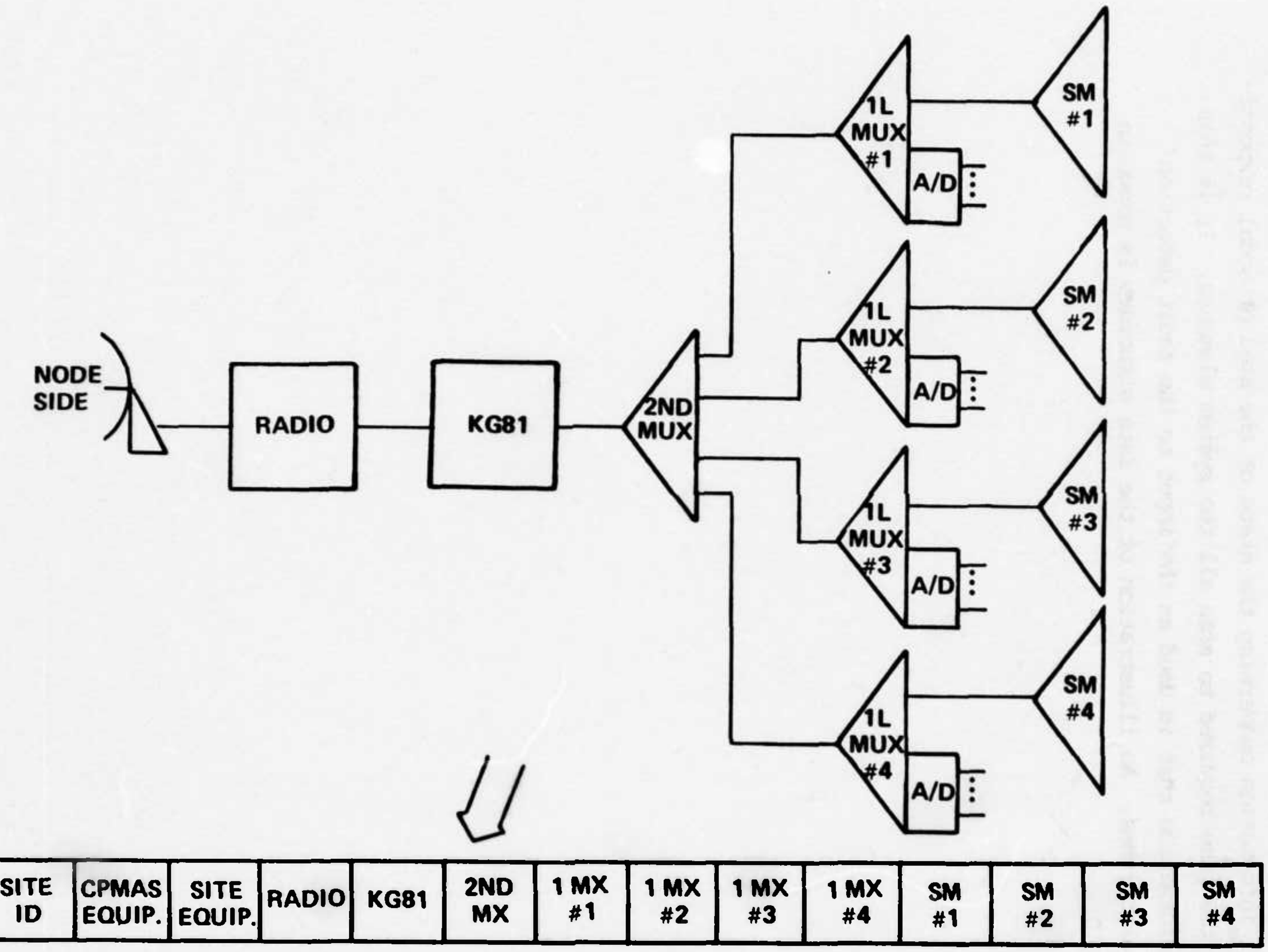


FIGURE D-2
RELATION OF EQUIPMENT STATUS MESSAGES WITHIN A SITE WORD FOR A TERMINAL STATION CONFIGURATION

furnish all information concerning the state of the area of nodal responsibility for the time required to scan all the system elements. It is this combined information that is used as the input to the fault detection/isolation algorithms. An illustration of the data structure is shown in Figure D-3.

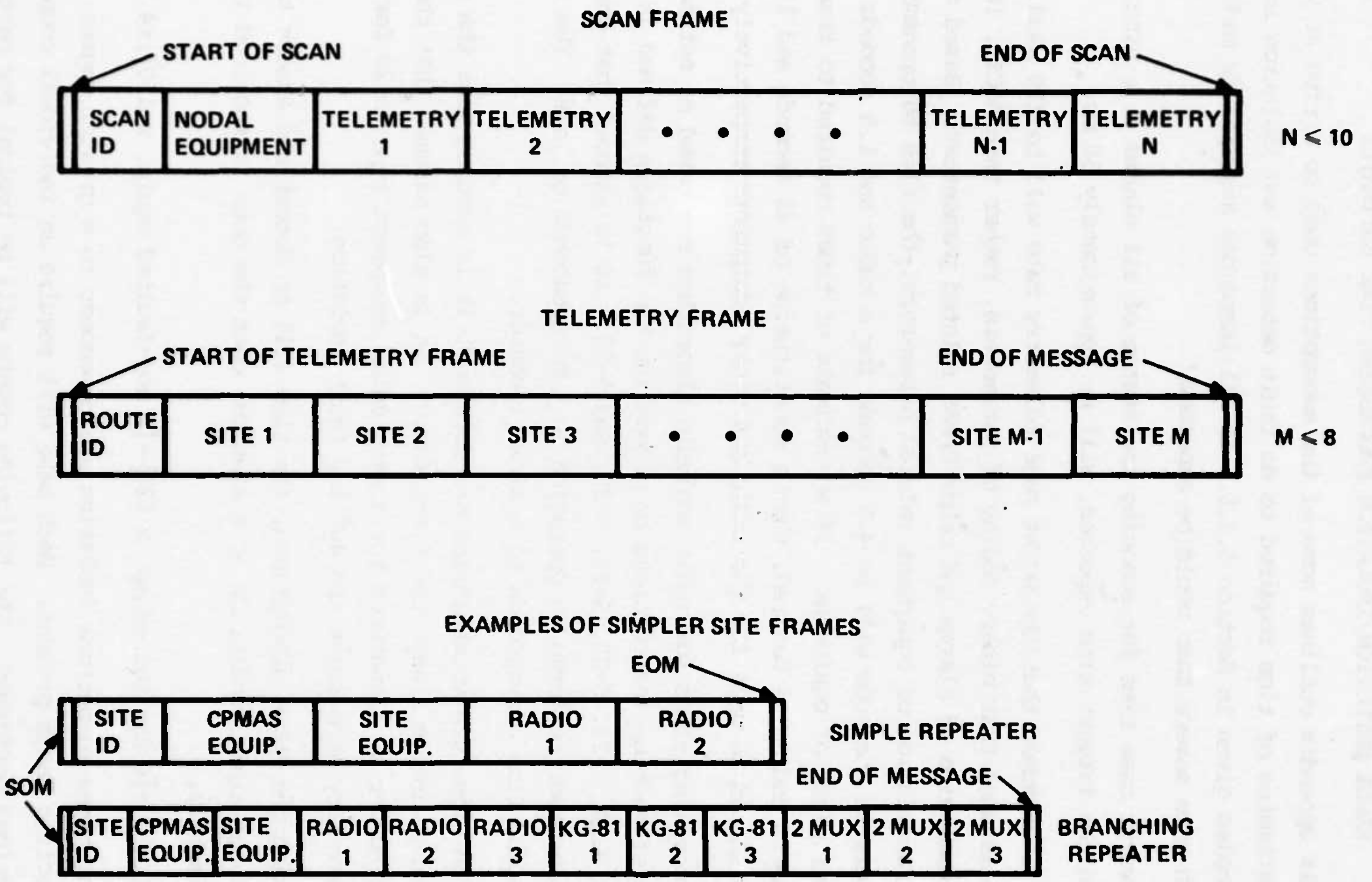


FIGURE D-3

FORMATTING OF DATA BASE

APPENDIX E

FAULT DETECTION/ISOLATION PROCESSING TIME ESTIMATES

This appendix outlines some of the assumptions used to arrive at very gross estimates of time required to do fault detection and isolation in the examples given in Section 5.3.5. In all instances assumptions made are much more severe than would be expected.

A worst case time for scanning the states of all alarms at a site, based on the largest site expected, will be approximately 50 ms.

It is assumed that the worst case telemetry rate will be 150 baud. It is also assumed that binary coding of parameters, rather than ASCII, is used for transmission of alarms and other CPMAS related parameters. Based on block transmission of equipment related parameters, the time to transmit parameters to the node will be 4.5 seconds for a radio and 1.5 seconds for any other piece of equipment. If an estimate of times required to transmit using ASCII coding is desired, then a substitution of 45 seconds and 15 seconds should be made for the radio and other equipments respectively.

Processing times for fault analysis algorithms are based on estimated numbers of machine instructions to accomplish the functions defined in Figures 5-20, 5-21, 5-22, 5-24, 5-25, and 5-26. It is assumed that the nodal processor performs an operation in 4 microseconds or less. The 4 microsecond time corresponds to a slow processor.

When signature vocabularies are accessed, it is assumed that the no-fault signature is always the first entry. It is also assumed that the average number of signatures for a particular equipment type is 20 for fault severity assessment and 400 for fault isolation.

Using the above assumptions, the time (T1) to detect and assess the severity of alarm conditions at a station, once the data is received is approximately,

$$T1 < (170 + [\#\text{ faulted equip. x } 625] + [\#\text{ non-faulted equip. x } 150]) \text{x4 usec.}$$

The times to perform isolation are dependent to a greater degree on the specific fault present. Each case will require an individual count of instructions performed. The following counts will be typical for part of the

fault isolation process. The number of operations to retrieve the fault message and related site parameters will be approximately 120. Each equipment inspected having no faults will require approximately 50 operations. For each equipment whose signature observed indicates a fault condition, it will be assumed that the signature desired will be the last entry in the vocabulary.

Example 1

Time to scan and detect at station < 50 ms.

Time to transmit radio data to node < 4500 ms.

Assume the site has the following equipments.

1 - facility equipment group
1 - radio set
2 - TED's
2 - 2nd level muxs
16 - 1st level muxs
----
22 - Total

The time to detect the fault and assess the severity at the node is given below.

$$T1<(170+625+21x150)x4 \text{ usec.}=3945x4 \text{ usec.}< 16ms.$$

The time to prioritize and queue the fault message is T2.

$$T2 < 2 \text{ ms.}$$

The total time to declare the alarm status at the site, T0, is then as shown below

$$T0<(50+4500+16+2)ms.=\underline{4.578 \text{ sec.}}$$

The required number of operations to isolate are summarized below.

Retrieve fault message and site parameters	- 120
Inspect non-faulted equipments	- 1050
Determine the matching signature	- 10000
Utilize signature definition to specify fault	- 550
Total	- 11720

Total time required < 46.88 msec.

Adding isolation time to the previous sum, the total time to isolate the fault is 4.625 sec.

Example 2

Time to scan & detect at the station < 50 ms.

Time to transmit to the node < 3000 ms.

Assume that both sites are configured as in example 1. The time to detect the fault and assess the severity at the node will be as shown below.

site A: 170+1250+3000 = 3420

site B: 170+1250+3000 = 3420

6840

Total time < 28 ms.

Time to prioritize and queue fault message < 4 ms.

The total time to declare the alarm status of both sites, T0, is then as shown below.

T0<50+3000+28+4= 3.082 sec.

Assume the sympathetically alarmed station has a higher priority in the queue. The isolation will consist of the operations outlined below.

Retrieve fault message and site parameters -	120
Inspect non-faulted equipments -	250
Determine matched reference signature -	10000
Utilize signature to implement jump -	1000
subtotal -	11370

The following operations will be performed for the faulted site.

Retrieve fault message and site parameters -	120
Determine matched signature for 2nd mux -	10000
Utilize signature to jump. -	1000
Determine matched signature for 1st mux -	10000
Utilize signature to specify fault -	550
subtotal -	21670
total -	33040

total time < 133 ms.

The total time to isolate for this example is then 3.115 sec.

Example 3

Time to scan and detect < 50 ms.

The worst case transmission time will be the one which comes from the station with the greatest number of alarmed equipments. In this case, let us assume that it is site C with 1 2nd level mux and 4 1st level muxs alarmed for a total of 5 blocks of data.

Time to transmit alarms to node < 7.5 sec.

The time to transmit data from sites A and C is sufficiently long such that site B's data will have been detected and queued before the arrival of data from sites A and C. Assuming sites A and C are configured as in examples 1 and 2, there will be 22 equipments at the site. The sites are identical so the time to detect and assess the severity of the alarms at each will be the same.

$$T1<(170+[5x625]+[17x1501)x4 \text{ usec.} < 24 \text{ msec.}$$

The time for both sites A and C will be < 48 msec.

The time to prioritize and queue the messages will be < 2 msec.

The maximum time to declare the alarms at all three sites will be as shown below.

$$TC<(50+7500+48+2)\text{msec.} = 7.6 \text{ sec.}$$

Assuming the worst case fault isolation process starting at site A, the estimate of the number of processor operations to isolate the fault is summarized below.

Retrieve fault message and parameters	120
Inspect non-faulted equipment	1050
Determine the matching signature	10000
Jump to site B's 2nd level mux #1	1000
subtotal	12170

At site B, the following operations will take place.

Retrieve fault message and parameters	120
Find reference signature for 2nd mux #1	10000
Jump to 2nd mux #2	1000
Determine matching reference signature	10000
Jump to TED #2	1000
Determine matching reference signature	10000
Utilize signature to specify fault	550
subtotal	32770
total	44940

Time to isolate 179,760 usec. $\lessdot$ 180 msec.

The total time to detect and isolate the fault is then 7.78 sec.

A number of observations can be made from the examples studied. First of all, the telemetry rate is the major factor influencing the minimum time to detect and isolate. Other considerations involving data processing are insignificant by comparison. While binary encoded transmission of data at a speed of 150 baud yields acceptable performance, it is doubtful that requirements of station alarm declaration at the node within 30 seconds can be achieved with ASCII coding at the same rate. Transmission times for sites are roughly proportional to the number of alarmed equipments at the site.

Faults which propagate sympathetic alarms throughout the system can be expected to increase the time to isolate. Faults which effect communications at the supergroup level or higher would cause multiple station alarms in routes served by strings inspected in the fault isolation process will be in the order of 120 msec. In any case involving sympathetically alarmed stations, the processing increase is linearly proportional to the number of stations involved.

The other factor effecting time to process a fault is the expected waiting time in the fault isolation work queue. Given the previous examples, one can assume a worst case average time to isolate for a site in the order of 500 msec. If a fault entered the queue with every other station (i.e., 15 max.) ahead of it, then a wait in the order of 8 sec. could conceivably take place (excluding time for operator interfaces, and requests for inter-nodal isolation to or from sector level).

APPENDIX F

ESTIMATE OF NUMBERS OF SIGNATURES FOR DRAMA EQUIPMENTS

A factor in the choice of a signature approach to fault isolation at the equipment level is the expected size of the signature database. This appendix presents an estimate of the number of signatures and signature definitions required for the DRAMA radio, 2nd level mux and 1st level mux. These equipments, since they incorporate the greatest number of alarms in their signatures, will have the greatest number of signatures and signature definitions.

AN/FRC 163 Radio

The following details how an estimate of the number of signatures for a radio was obtained. The number of possible signatures for the radio is somewhere in the range of 40 to 1,099,511,627,776 (2 to the 40th power). The following entries denote expected signatures. It is assumed that multiple independent failures within an equipment do not occur in a short span of time.

(1) Loss of power - A
(2) Loss of power - B
(3) Loss of power - A&B

The above three faults are assumed to occur independently of any other possible faults. The upper bound on the total # of possible fault signatures is $3+2^{38}$ = 274,877,906,947.

(4) Loss of timing in port 1 - A
(5) Loss of timing in port 1 - B
(6) Loss of timing in port 1 - A&B
(7) Loss of data in port 1 - A
(8) Loss of data in port 1 - B
(9) Loss of data in port 1 - A&B
(10) (6)&(9)

The set above are likely failure modes where signature bits #'s 1, 2, 7, 8 are involved, without other independent failures within the equipment. If we make the same assumption for bits 3, 4, 9, and 10 and 5, 6, 11, and 12;

a total of 21 fault signatures are obtained from the 12 bits. The upper bound on the number of possible signatures becomes $24+2^{26} = 67,108,888$.

(25) Loss of modulator output - A

(26) Loss of modulator output - B

The upper bound is now $26+2^{24} = 16,777,242$.

(27) Transmitter frequency drift - A

(28) Transmitter frequency drift - B

(29) Transmitter frequency drift - A&B

The upper bound = $29+2^{22} = 4,194,333$.

(30) Power alarm - A

(31) Power alarm - B

(32) Power alarm - A&B

The upper bound = $32+2^{20} = 1,048,608$.

(33) Loss of demodulator output - A

(34) Loss of demodulator output - B

(35) Loss of demodulator output - A&B

The alarm states of other receiver alarms associated with the above can be expected to be a fixed pattern, i.e., only one set of binary states would be associated with each of the above.

(36) BER alarm - A

(37) BER alarm - B

(38) BER alarm - A&B

Bit error rate alarm may or may not be accompanied by other alarms depending on the severity of the error rate. The above assume independent occurrence of signature bits 21 & 22. The upper bound on the total number of possible fault signatures is now, $38+2^{16} = 65,574$.

(39) Receiver AFC - A

(40) Receiver AFC - B

(41) Receiver AFC - A&B

(42) (39)+(36)

(43) (40)+(37)

(44) (41)+(38)

Receiver frequency drift could conceivably take place alone or accompanied by BER alarm or possibly other alarms to be detailed later. The upper bound on the number of possible alarms is now $44+2^{14} = 16,428$.

Loss of frame synchronization could possibly be independent of other alarms or accompanied by the above patterns (36) to (44).

(45) Loss of frame - A
(46) Loss of frame - B
(47) Loss of frame - A&B
(48) (45)+(36)
(49) (46)+(37)
(50) (47)+(38)
(51) (45)+(39)
(52) (46)+(40)
(53) (47)+(41)
(54) (45)+(42)
(55) (46)+(43)
(56) (47)+(44)

In any case loss of frame would be accompanied by a fixed set of alarms the MBS outputs. The upper bound on the number of signatures required is now, $56+2^{12} = 4,152$.

The remaining twelve bits related to loss of MBS outputs.

(57) Loss of MBS out port 1 - A
(58) Loss of MBS out port 1 - B
(59) Loss of MBS out port 1 - A&B
(60) Loss of timing out port 1 - A
(61) Loss of timing out port 1 - B
(62) Loss of timing out port 1 - A&B
(63) (59)+(62)

By the same reasoning ports 2 and 3 will also yield seven signatures each for a total of 77 signatures for the radio.

2nd Level Multiplexer

The following details the basis for the estimate for the number of signatures associated with a 2nd level mux. The initial range for the

number of signatures is between 42 and 2^{42}.

(1) Loss of power - A&B

(2) Loss of power - A

(3) Loss of power - A with fault alarm (WFA)

(4) Loss of power - B

(5) Loss of power - B WFA

(6) Fault alarm - A

(7) Fault alarm - B

(8) Fault alarm - A&B

Loss of digroup inputs and outputs where redundant failures occur can usually be related to a sympathetic alarming due to failure of another connected equipment. Because of the large number of combinations possible with eight ports, there will be many possible signatures. However, only eight definitions related to loss of input ports and eight related to loss of output ports where there is redundancy are needed. In this case while all the signatures may exist, many of the signatures will share a common definition.

The total number of combintations for loss of input ports is given by,

$$\binom{8}{1}+\binom{8}{2}+\binom{8}{3}+\binom{8}{4}+\binom{8}{5}+\binom{8}{6}+\binom{8}{7}+\binom{8}{8}= 255$$

It is not known which of these signatures would be required because of actual implementation in the DCS. Assuming that multiple failures within an equipment do not occur in a short period of time, there will be 16 signatures related to loss of digroup data/timing in on some port on the A or B redundant units. There will also be another 16 if the fault occurs with a fault alarm. The total number of signatures related to faults involving digroup inputs is then 287. Likewise there are 287 signatures for loss of digroup outputs for the mux. It should be noted that the total number of signature definitions related to the 574 fault signatures is only 32.

The total number of signatures present is now 582.

(583) Loss of MBS data/timing out - A

(584) Loss of MBS data/timing out - B

(585) Loss of MBS data/timing out - A&B

(586) Loss of MBS data/timing in - A

(587) Loss of MBS data/timing in - B

(588) Loss of MBS data/timing in - A&B

(589) (583) WFA

(590) (583) WFA

: : :

(592) (587) WFA

(593) Loss of frame - A

(594) Loss of frame - B

(595) Loss of frame - A&B

(596) (593) WFA

(597) (594) WFA

The total number of signatures for the 2nd level mux is approximately 597, assuming no multiple independent faults within an equipment. The total number of signature definitions corresponding to this vocabulary is somewhat smaller numbering approximately, 64.

1st Level Multiplexer

The following is the basis for the estimated number of signatures required for a 1st level mux.

(1) Loss of digroup input

(2) Loss of digroup input with fault alarm (WFA)

(3) Loss of digroup output

(4) Loss of digroup output WFA

(5) Power supply alarm

(6) Loopback Alarm

The remaining signatures are related to the digital channel I/O ports. As in the case of the 2nd level mux, a large number of ways of 12 ports failing 1,2,3,...,12 at a time exist. It is assumed as before that multiple independent failures within an equipment are highly unlikely in the short time period associated with a scan. Failure of more than one port, but less than all; may usually be related to sympathetic alarming of failures in

connected equipment. Failure of one or all, may or may not be related to external causes. In any case, only one channel will have to be traced to its source to isolated sympathetically alarmed faults. The number of signature definitions required to do this will be 48. The total number of signatures is given by,

$$\binom{12}{1}+\binom{12}{2}+\binom{12}{3}+\binom{12}{4}+\binom{12}{5}+\binom{12}{6}+\binom{12}{7}+\binom{12}{8}+\binom{12}{9}+\binom{12}{10}+\binom{12}{11}+\binom{12}{12}=4095$$

for input ports and the same number will be needed for channel outputs. Twenty four of these are assumed to occur within the equipment and may have fault alarms associated with them. The resulting totals for the number of signatures and signature definitions are,

# of signatures = 8220

# of signature definitions = 52

APPENDIX G

DNC FUNCTIONAL DESCRIPTION

Digital Network Control can be functionally divided into two parts, channel reassignment and control. Channel reassignment is provided by the Digital Control Element (DCE) and is the function which makes automatic DNC possible. Control refers to the control and coordination of the DCEs in a network, and interfacing the DCEs with man.

G.1 Digital Control Element (DCE) Description

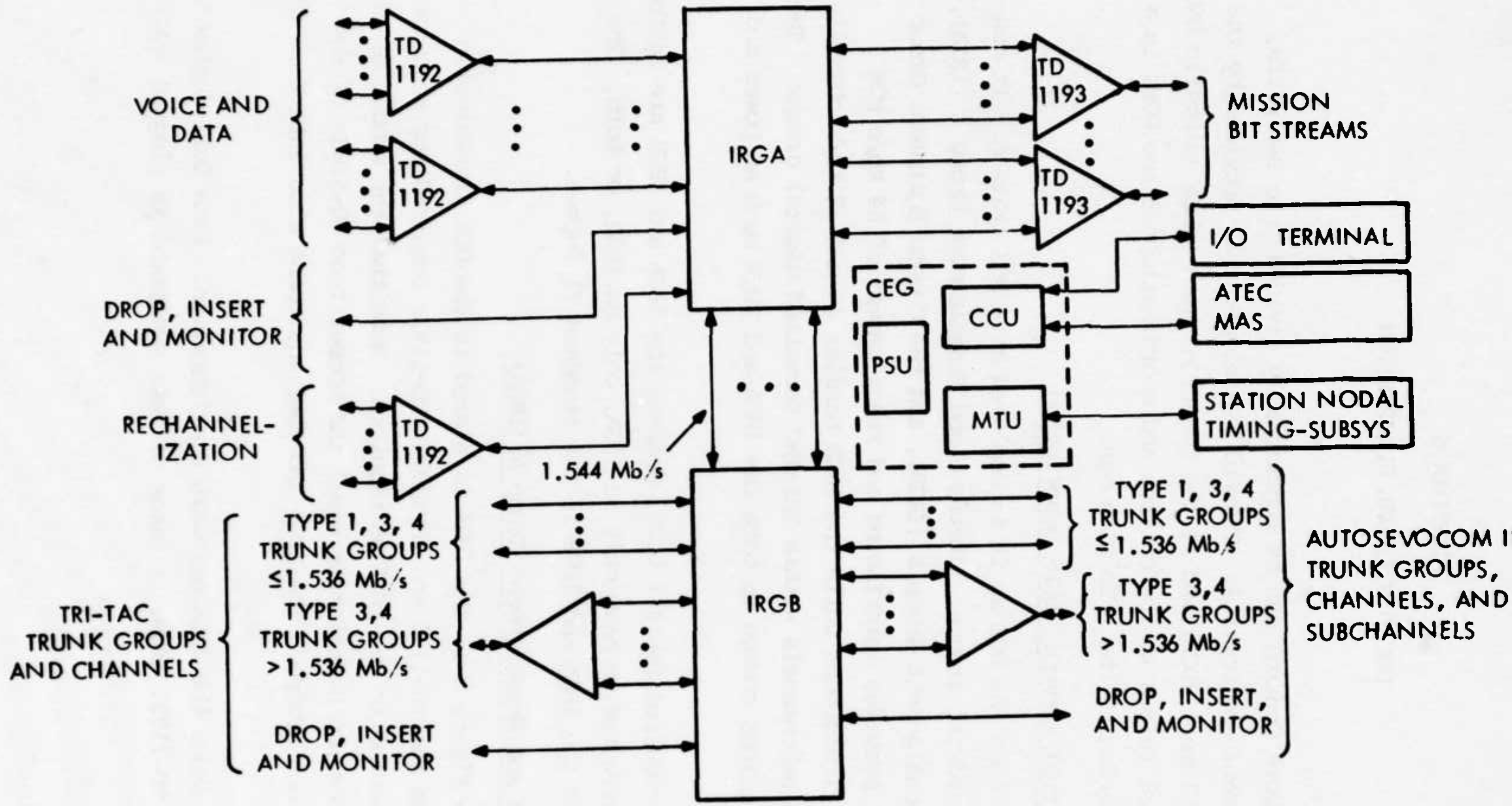
Figure G-1 shows the DCE as it is deployed at a DCS station. It consists of three hardware groups, Interface and Reassignment Group A (IRGA), Interface and Reassignment Group B (IRGB), and the Common Equipment Group (CEG). The IRGA provides interfacing and reassignment of 64 kb/s PCM channels within T1 digroups while the IRGB handles 16 and 32 kb/s channels and 2 and 4 kb/s subchannels within TRI-TAC formatted digital groups. The CEG provides functions common to both the IRGA and IRGB such as power and timing.

The CEG is required for all DCEs, whereas the IRGA and IRGB are optional. A DCE may be configured to have only an IRGA, only an IRGB, or both. The interface between the IRGA and IRGB is the standard T1 format.

G.1.1 Interface and Reassignment Group A (IRGA)

As shown in Figure G-1, the IRGA is placed in the DCS transmission hierarchy between the TD-1192 and TD-1193. TD-1192s required for rechannelization are connected to the IRGA as required. Note that the number of T1s from TD-1192s does not necessarily equal the number from TD-1193s of the presence of through groups. The IRGB and test equipment also interface the IRGA as T1s.

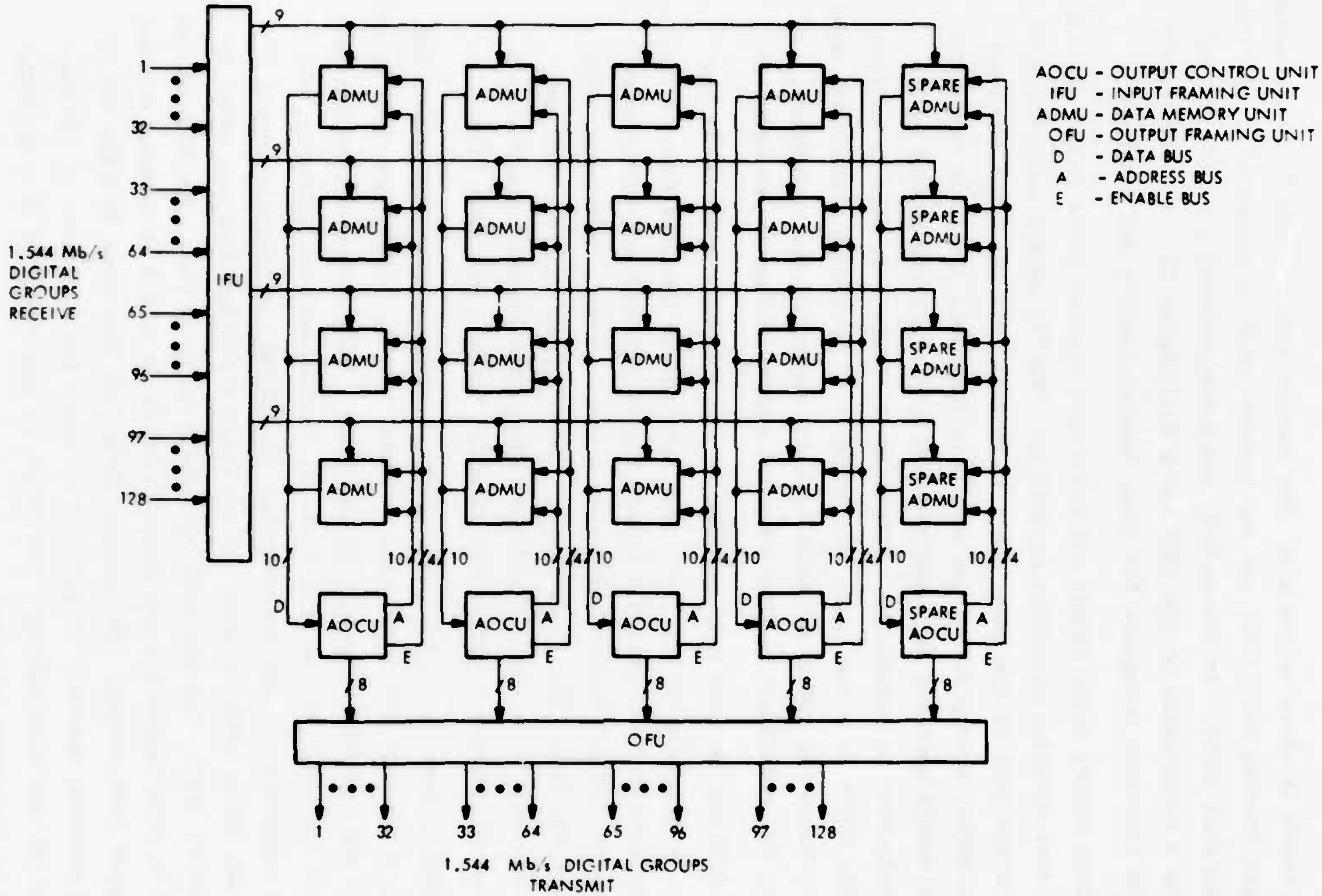
Figure G-2 shows the IRGA hardware configuration. Each full-duplex T1 from a TD-1192, TD-1193, IRGB, or piece of test equipment is plugged into a



NOTE :

IRGA - INTERFACE AND REASSIGNMENT GROUP A
IRGB - INTERFACE AND REASSIGNMENT GROUP B
CEG - COMMON EQUIPMENT GROUP
CCU - CENTRAL CONTROL UNIT
MTU - MASTER TIMING UNIT
PSU - POWER SUPPLY UNIT

FIGURE G-1. DCE - STATION CONFIGURATION



NOTE: CONFIGURED FOR A MAXIMUM OF 128 DIGITAL GROUPS

FIGURE G-2. INTERFACE AND REASSIGNMENT GROUP A

connector which is wired to the DCE. The receive side of each T1 is connected to the Input Framing Unit (IFU) and the transmit side is connected to the Output Framing Unit (OFU). In Figure G-2, the ports numbered 1 on the IFU and OFU make up a termination on the IRGA for a full-duplex T1. The IFU and OFU provide the functions necessary for frame synchronization and alignment.

The Data Memory Units (ADMU) and the Output Control Units (AOCU) provide a digital time division switching capability. The "A" prefix indicates that these units are part of the IRGA. Data is written into the ADMUs and read out by the AOCUs, accomplishing the switching function. Analysis has determined that double buffered data memories and byte transfers result in the greatest reduction in redundancy. Referring to Figure G-2, data is written into all the ADMUs in a row (i.e., all ADMUs in a row always contain the same data bits), hence the number of ADMUs in a row indicates the redundancy. In the figure, the redundancy is four (the hot standby column is not counted).

Each AOCU can be read from any ADMU in its column; therefore, it has access to the data bits of all T1s. Each row handles the data from 32 T1s. After conversion to 8-bit parallel bytes, the 32 digroups are multiplexed together in the IFU and then written into a row of ADMUs. Similarly, each AOCU handles the output for 32 digroups. The OFU demultiplexes them and converts them back to serial. The figure shows nine parallel lines into a row from the IFU because a parity bit is added to the eight data bits.

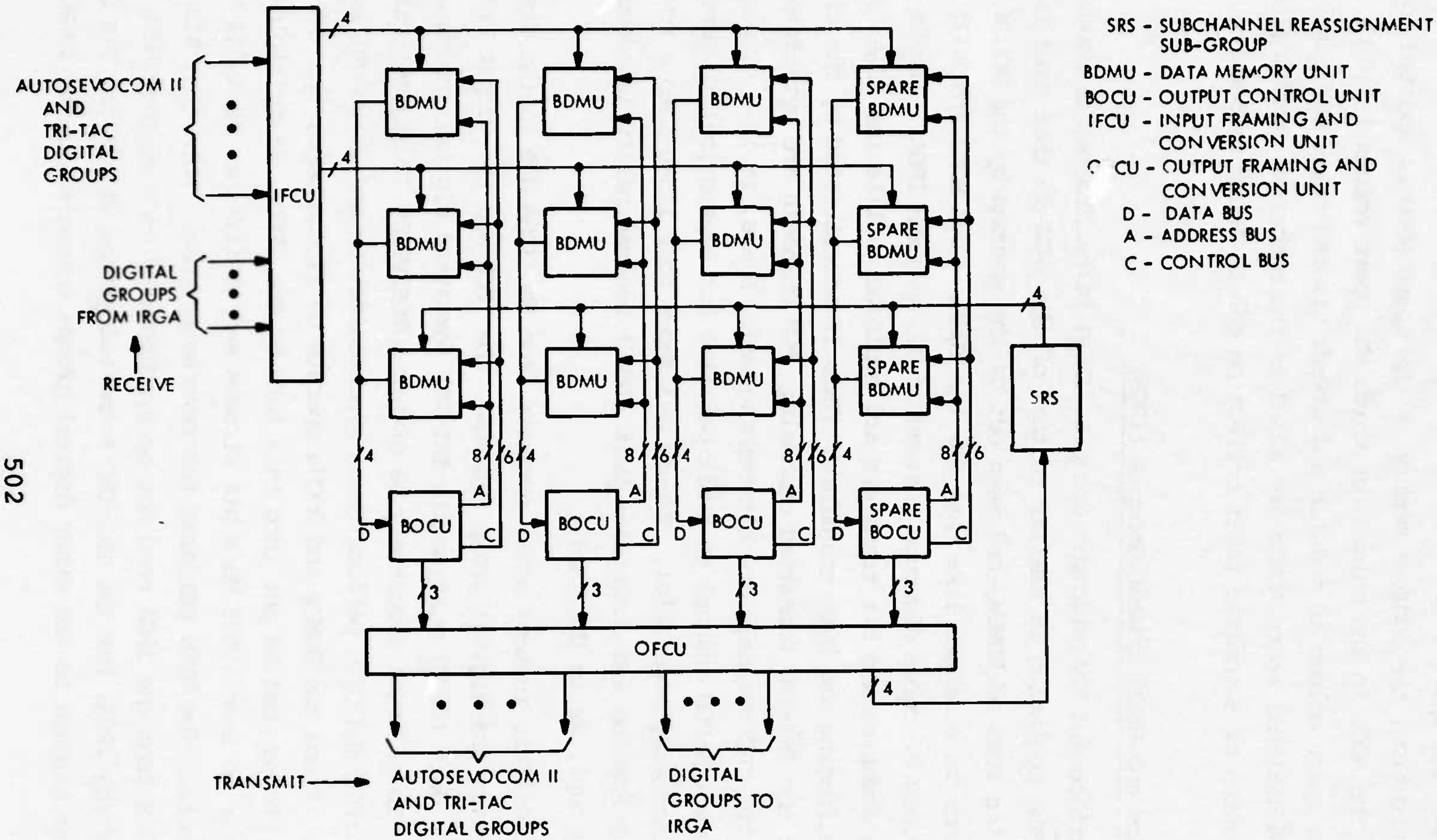
The IRGA is modular in groups of 32 T1s. Ignoring the spare column for the moment, a minimum IRGA would have one ADMU (in the figure, the ADMU in the upper left) and one AOCU (the AOCU on the left). This configuration can handle up to 32 T1s which may be from first-or second-level multiplexers, the IRGB, test equipment, or any combination. To expand, immediately beyond 32 digroups, the three ADMUs adjacent to the upper left-hand ADMU are added as well as another AOCU. Now the IRGA can handle up to 64 T1s. The IRGA can be configured in this manner for any multiple of 32 up to 192 by growing outward from the upper left corner. The largest IRGA (192 T1s) uses 36 ADMUs and 6 AOCUs (not counting spares). Figure G-2 is shown for a maximum of 128 T1s. The IFU and OFU are also modular, the former in increments of five digroups and latter in increments of eight.

The spare units are provieed for automatic fault correction. Selectors in the OFU allow the spare column to substitute for any other IRGA column. Prior to substitution, the address memory in the spare AOCU is updated to match that of the AOCU in the column for which the spare column is to be substituted. The spare column is modular and always has one spare ADMU and the spare AOCU. Additional spare ADMUs are added as the number of rows increases. Further discussion of automatic fault correction can be found in Section G.3.4.

G.1.2 Interface and Reassignment Group B (IRGB)

The Interface and Reassignment Group B (IRGB) block diagram is shown in Figure G-3. The operation is similar to that of the IRGA in that data is written into the rows of BDMUs, and read out of the columns by the BOCUs. The IRGB expands in a manner like that for the IRGA. Each BDMU and BOCU accepts a maximum of three digroups instead of 32, as with IRGA. Single buffered data memories and bit transfers are employed, unlike the IRGA, which uses double buffering and byte transfers. This is necessitated by the different format of the TRI-TAC formatted channels. PCM channels are byte-interleaved while TRI-TAC channels are bit-interleaved. Hence, it is a simple matter to convert a PCM channel to 8-bit parallel but impractical to convert the TRI-TAC channels to parallel. Figure G-3 shows four lines into a row from the Input Framing and Conversion Unit (IFCU) because parity is added to the three digroups, as in the IRGA.

The IRGB differs in many other respects from the IRGA due to the different channel rates and digital group formats. The IFCU and the Output Framing and Conversion Unit (OFCU) must handle TRI-TAC formatted digital groups as well as T1s. These trunk groups may be either AUTOSEVOCOM II or tactical groups. The IFCU and OFCU perform frame synchronization and alignment for these groups. Since the BDMUs and BOCUs operate on T1 digroups, the TRI-TAC format trunk groups must be put into this form by the IFCU. It multiplexes groups together to form 1.536 Mb/s bit streams and stuffs this to 1.544 Mb/s, the digroup rate. The OFCU performs the reverse process. Note that T1s coming to the IRGB from the IRGA need not be synchronized because they have already been by the IRGA, but the TRI-TAC formatted groups within the T1s must be major-frame aligned to the other digital groups connected to the IRGB.



NOTE: CONFIGURED FOR A MAXIMUM OF 3 1.536 Mb/s DIGITAL GROUPS TERMINATING AT THE DCE

FIGURE G-3. INTERFACE AND REASSIGNMENT GROUP B

The groups in the T1 are already minor-frame aligned with respect to the IRGB digital groups because the T1 is frame aligned to the internal IRGB digroups, as mentioned above, and because the T1 frame period is a multiple of the TRI-TAC format minor-frame period. If no IRGA is deployed, then the IRGB must synchronize and align any T1s connected to it.

The IRGB also contains a Subchannel Reassignment Subgroup (SRS) which handles reassignment of 2 and 4 kb/s subchannels. It accepts up to three internal T1 digroups from the BOCUs. The BOCUs extract overhead channels from the digital groups and insert them in the digroups to the SRS. The SRS stores an entire major-frame of overhead channels, giving it access to each subchannel. After reassignment of the subchannels, the overhead channels are sent to a row of BDMUs where the BOCUs can then insert the subchannel reassigned overhead channels back into their proper places. The SRS contains an SDMU and an SOCU which are very simialr to the BDMU and BOCU in operation. Alternative approaches to subchannel reassignment involve special hardware to extract overhead channels from the trunk groups. This is a more complex and more expensive approach than using the BDMU/BOCU extraction method just described.

An important factor in the operation of the IRGB is the relationship between the T1 and TRI-TAC formatted frame periods. The T1 frame period is 125 msec while for 16 kb/s digitalization the TRI-TAC format minor frame period is 62.5 msec and for 32 kb/s digitalization the monor frame period is 31.25 msec. This means that the T1 frame period is an integral multiple of the TRI-TAC format minor frame which allows the T1s and digital groups to be aligned such that the start of a minor frame coincides with the start of a T1 frame. Also, each T1 frame with 16 and 3w kb/s channels imbedded in it will contain two bits from each 16 kb/s channel and four bits from each 32 kb/s channel.

G.1.3 Common Equipment Group (CEG)

The CEG as shown in Figure G-4 consists of the hardware common to both the IRGA and IRGB. The Central Control Unit (CCU) controls the hardware discussed above and interfaces it to the outside world. The CCU connects to the hardware via a bus system; to the ATEC Communications Interface Function (CIF) which provides a link to both the station controller's terminal and the Nodal

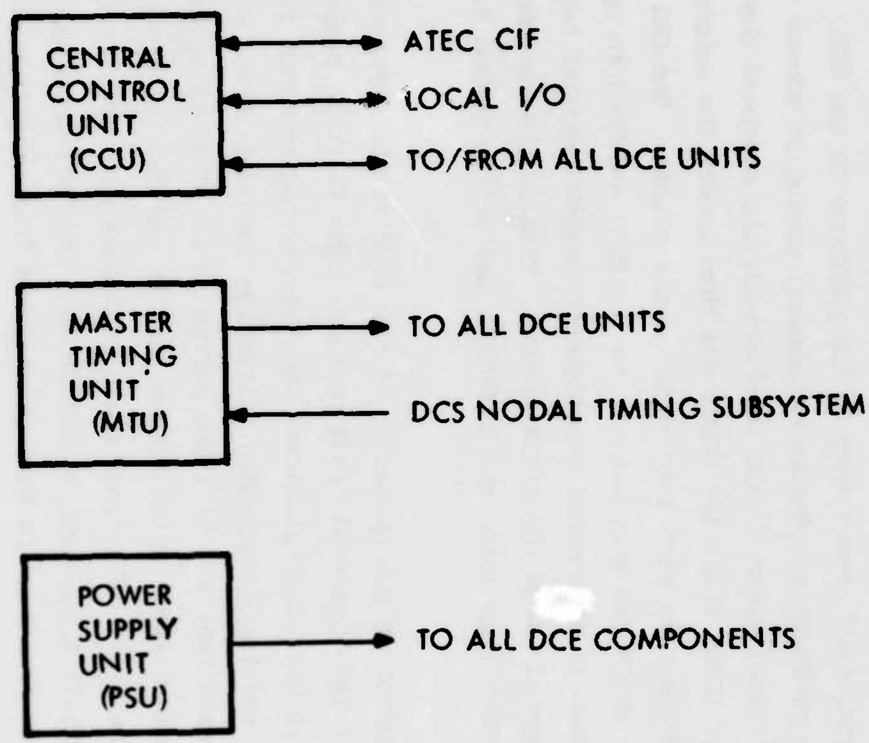


FIGURE G-4. COMMON EQUIPMENT GROUP

Control Subsystem (NCS); and to a local terminal for backup purposes.

The Master Timing Unit (MTU) receives a master clock signal from the DCS station timing subsystem or derives it from the appropriate transmission link. Based on this master signal, the MTU generates all timing signals needed by the DCE. It also provides a free-running capability in the event of a failure in the master timing source. The Power Supply Unit (PSU) provides power to the IRGA, IRGB, CCU, and MTU.

G.2 DCE Control

As the ratio of communications cost to processing costs increases, it becomes advantageous to place more control functions near the system or device to be controlled rather than centralizing all control functions. A properly designed decentralized control system has the added advantage of increased performance, availability, and survivability. Control of the DCEs is to be provided by a hierarchical structure which is physically integrated into the planned DCS system control subsystem. This realizes the advantages described above and additional cost savings by permitting the sharing of facilities between DNC and system control.

The basic control hierarchy is shown in Figure G-5. Control flows downward in the structure while status information flows upward. Station nodal and sector personnel access and control the DCE via ATEC. For example, both the DCE and the Station Controller Terminal Function are connected to the colocated Communication Interface Function at a station and would communicate through this device. Should ATEC fail to be deployed, DNC would utilize whatever manual or automated control and information distribution system is implemented at the three lower levels of the planned system control subsystem. The ACOC could access a DCE automatically through ATEC or, as is the recommended approach, indirectly by voice or record communication with sector personnel. A display may be plugged directly into the DCE for fallback purposes if trouble occurs within ATEC. The advantage of this DCE access and control scheme is that it uses the planned ATEC communications facilities instead of requiring a separate control system. The effect of this decision on the human interface is discussed further in Sections G.3.1 and G.3.2.

Functional control of the DCE hardware is distributed between the DCE'CCU and software located at the node and sector levels. The software which inter-

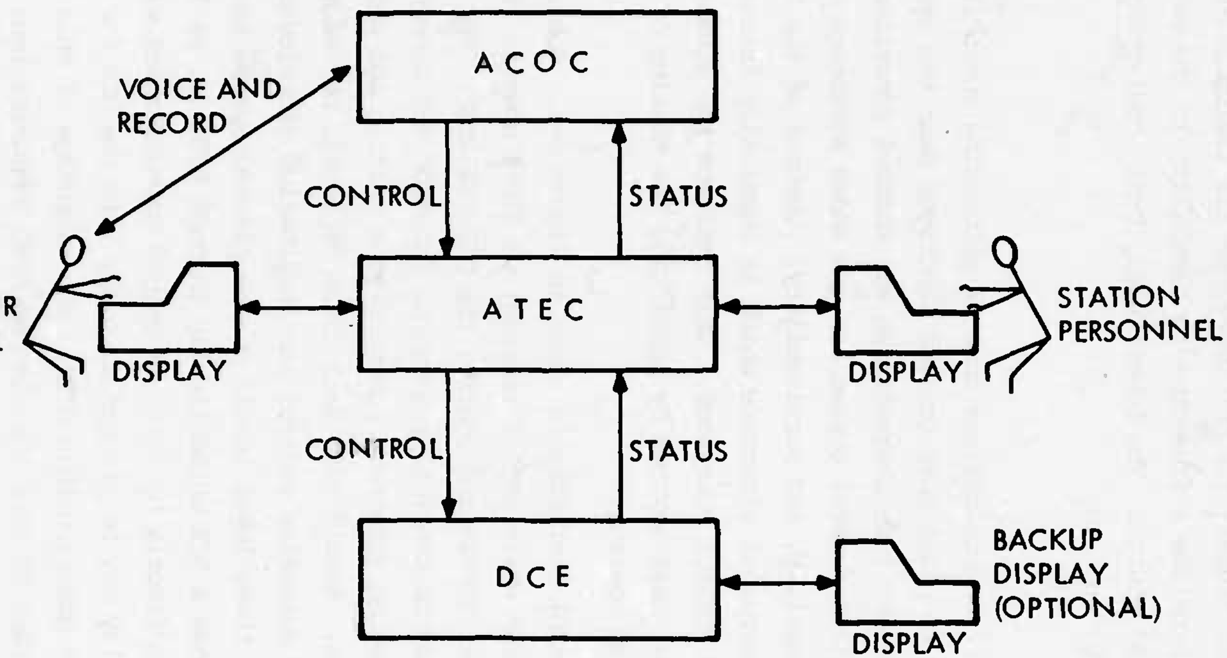


FIGURE G-5. DCE CONTROL HIERARCHY

faces the DCE with system control personnel is located in the Nodal Control Subsystem (NCS) and the Sector Control Subsystem (SCS) of ATEC because this places it closer to the point where most control decisions are made. This is beneficial since it permits easy access to the ATEC data base located in an NCS or SCS. The DCE control software will need the infomration in the data base so colocating the two eliminates the need for a duplicate data base for the DCE. Alternatively, this software could run on the CCU and access the nodal data base via the ATEC communications facilities, but this approach would result in a higher load placed on these facilities by the DCE than if this software were colocated with the data base. Also, the DNC software in the NCS and SCS can share some software with ATEC, such as data base and I/O routines.

The CCU provides control of alterations to the address memories and of fault detection and isolation within the DCE. These functions are placed within the DCE because this puts the control near what it is controlling. A larger burden would be placed on the ATEC communications facilities if these functions were placed in the NCS. Some human interface functions are performed by the CCU in order to support the backup display.

G.3 Operational Algorithms

The operational algorithms of Digital Network Control can be classified into five categories: man/machine interface, functional algorithms, fault tolerance, initialization and recovery, and synchronization. These algorithms encompass both implementation aspects (e.g., synchronization procedures) and control aspects (e.g., DCE operational commands) of DNC. Each of the five categories is discussed below.

G.3.1 Man/Machine Interface

The normal man/machine interface for DNC consists of an ATEC Controller Terminal Function (CTF) and the software to support it. According to human engineering principles, one common control console is perferable to two separate panels. With this commonality it is then important that the type of dialogue that personnel conduct with DNC software be the same as the type of dialogue used with ATEC. For example, if ATEC employs a prompt-oriented dialogue where the user fills in blanks and makes selections, then DNC must also use this type of dialogue. Similar types of dialogues for the various

system control functions help to reduce training time and operator error.

A dialogue type is not specified in the ATEC System Description Requirements Document, so for this study a simple command/response system was assumed. System Control personnel enter a DNC command at a CTF and this command is sent to a SCS or NCS. There the DNC software analyzes the command and if the command is invalid in some respect, returns an error message. If the command is valid, the software accesses the data base and generates and transmits the appropriate machine-level commands to the DCEs. Upon completion of the operation, a message is returned to the controller who originated the command which indicates the successful execution of the command. If the command could not be executed, the reason for the failure is provided.

All commands will return some response within 10 seconds from the time the command is entered. Commands which take longer than 10 seconds to complete will return an acknowledgement to let the controller know that the command was accepted. Again, this is only a preliminary dialogue structure chosen for its simplicity. If a different type is specified for ATEC, DNC will conform to that approach.

G.3.2 Functional Algorithms

The DCE must be designed to be flexible in order to accomodate new functions and control algorithms different from those described here. DNC functions are classified into two groups, static and dynamic. Static functions are long-term functions in which the related channel connectivity remains relatively fixed. Dynamic functions are those which are employed for more frequent connectivity changes.

G.3.2.1 Static Functional Algorithms

DCE Static functional algorithms provide for the elimination of backhauling, network flexibility (rechannelization), TRI-TAC interface, AUTOSEVOCOM II interface, and equipment savings. These are based on the DCE's ability to connect any channel to any other channel on a long-term basis while the dynamic functions are based on the ability to alter the channel connectivity.

When a DCE is installed at a site, a data base is generated for the SCS/NCS with jurisdiction over the site. This data base contains the channel

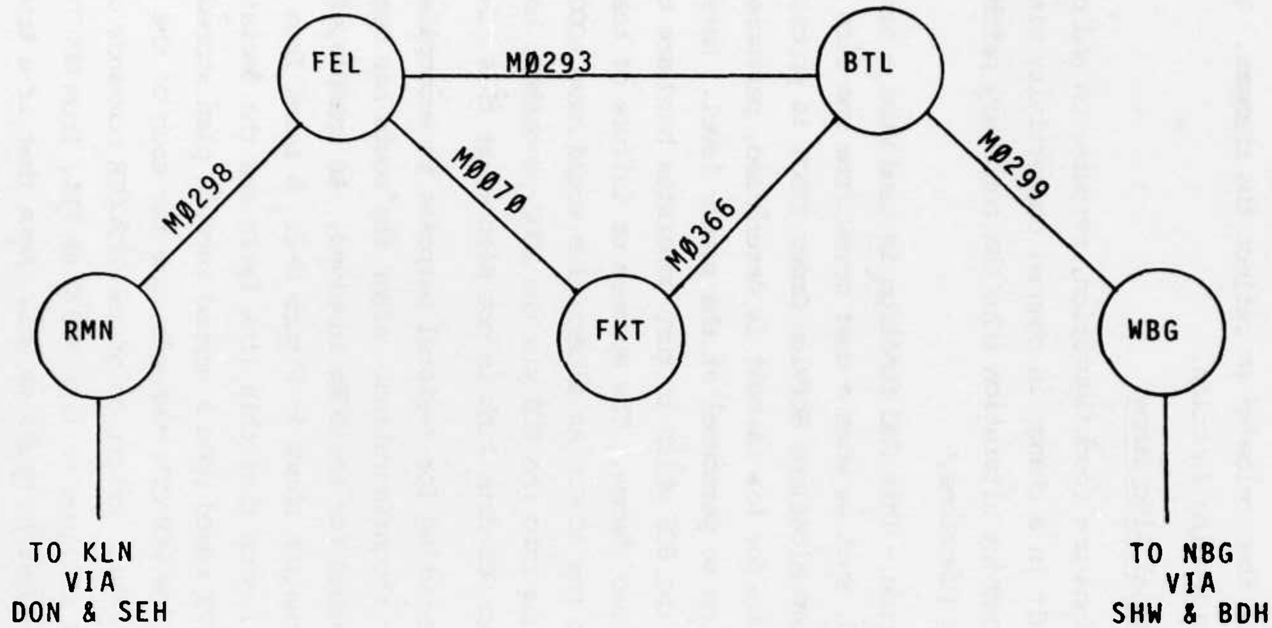
connectivity which provides the static functions listed above. If changes are required, data base routines are used to update the data base. The address memories in the DCEs are then reloaded to reflect the changes. The DCE load command performs this reloading function.

G.3.2.2 Dynamic Functional Algorithms

Dynamic DNC functions are reconfiguration, reroute, on and off-line test, and loopback. All result in a change in channel connectivity with reconfiguration being a more permanent alteration than the temporary patch performed by the other three dynamic functions.

G.3.2.2.1 Reconfiguration - This DNC function is used when a circuit within the DCS is reconfigured, such as when a user moves from one site to another. After the user's Telecommunications Service Order (TSO) is processed and the new route through the DCS for his circuit is determined, personnel at the ACOC communicate this decision to personnel at the sector level. Here, ASSIGN commands are entered into the SCS which in turn generates hardware commands to the DCEs involved in the route change. The success or failure of the operation is communicated back up to the ACOC. An alternative would have ACOC personnel enter the ASSIGN commands into the SCS via the ACOC processor; however, a direct ACOC processor to SCS data link is not planned at this time.

G.3.2.2.2 Reroute - Rerouting for restoral purposes is accomplished in a manner similar to that for reconfiguration. After the route has been selected, REROUTE commands are issued for the DCEs involved. An example of a reroute action involves the situation shown in Figure G-6. A trunk from KLN to NBG traverses link MO293. Assume that this link fails and the decision is made to reroute the trunk via FKT based upon a canned reroute plan stored in ATEC. The plan consists of three REROUTE commands, one for each of the three sites involved (FEL, BTL and FKT). Execution of the REROUTE commands causes the trunk in question to be rerouted to link M0070 at FEL, from M0070 to link MO366 at FKT, and from MO366 to MO299 at BTL. Note that if a trunk existed from FEL to BTL via FKT and this trunk was used for the reroute, then there is no need to alter the connectivity at FKT and therefore, the reroute plan would not contain a REROUTE command for FKT.



TRUNK FROM KLN VIA DON, SEH, RMN, FEL, BTL, WBG, SHW, BDH TO NBG

FIGURE G-6. REROUTE SCENARIO

The controller who initiated execution of the plan can modify it depending upon the current circumstances prior to initiating execution of the plan. If none of the plans are satisfactory, the controller can create new plans made up of REROUTE commands. Alternatively, REROUTE commands can be issued directly without first creating a canned reroute plan in the SCS or NCS.

When the link is returned to service, the reroute is terminated. This action causes REROUTE TERMINATE commands to be executed for each site involved. In the example, the connectivity for the trunk would be restored to what it was prior to the reroute. Any trunks which are preempted would be automatically reconnected in their original configuration. For directly issued REROUTE commands the controller must issue the corresponding REROUTE TERMINATE commands.

Which level in the system control hierarchy initiates the reroute depends upon the extent of the reroute. If the reroute is solely within a node or sector, then it can be handled by the appropriate NCS or SCS. If the reroute spans more than one sector, then either the ACOC must coordinate the activities or the sectors involved must coordinate.

G.3.2.2.3 On and Off-Line Tests - These two functions are used in conjunction with ATEC performance assessment and fault isolation procedures. The TEST, LOOPBACK, and MONITOR commands provide system control personnel with the capability to connect test gear to circuits and to loopback circuits. For example, when connecting a new access circuit from a station to a user, it could be checked out from the user location by looping the circuit back at the station. These commands could be used by ATEC directly, but most likely the off-line commands (TEST and LOOPBACK) will require human approval because they interrupt service.

The TEST command is used to check a circuit in an off-line mode. It provides the capability to connect a digital signal generator to the transmit side of a channel and digital signal analyzer to the receive side of the channel. The LOOPBACK command provides for looping back a channel in either direction. These two commands, TEST qnd LOOPBACK, can be used jointly. For example, one end of a circuit is connected to test equipment and the other end is looped back. This test configuration can be implemented between any two stations in a circuit. The MONITOR command is an on-line command used to connect test equipment to a channel without interrupting service on that channel.

G.3.3 Fault Control

Fault control refers to the spectrum of actions taken to reduce the effects of faults and errors on system performance. There are several methods for dealing with faults: avoidance, detection, isolation, correction, and tolerance. Avoidance refers to design methodologies used to avoid design errors. Detection, isolation and correction deal with faults that actually occur and attempt to repair the failure. Tolerance refers to the system's ability to continue operation, possibly in a degraded mode, after a fault has occurred Faults can occur both in hardware and software and both types are discussed below. The two are not independent in that hardware can check for software errors and vice versa.

G.3.3.1 Hardware Failures

Hardware faults fall into three phases during the life of a device. The first phase consists mainly of manufacturing and design errors. After these are debugged, the second phase is entered which consists of Poisson distributed failures resulting from hardware deterioration. The final phase occurs near the end of the device's life when the incidence of failures increases. Fault control techniques for hardware are aimed at the second phase.

There are many techniques available for achieving a given level of hardware reliability and many are used in the DCE. Some, however, are too expensive for this application. Using high reliability components gets the problem at its source, while Triple MODULAR Redundancy (TMR) provides three copies of critical circuits and adds a voter circuit to output the majority result. Both techniques are better suited to systems which require very large MTBFs, such as spacecraft where manual repair is difficult or impossible. The DCE can be easily repaired by personnel and hence, the costs incurred by these two techniques are not warranted.

Three techniques are used in the DCE to detect hardware faults. In the first technique, parity bits are added to data words to check for problems in the data and address memories of the DMUs and OCUs, and to check the busses connecting them. Parity bits are also added to information flowing between the CCU and other DCE units. Hardware parity checkers are employed in the DCE, with the exception that information going to the CCU is checked by software.

The second detection technique involves a comparison similar to the voting action of TMR. The output of an off-line unit is compared with that of an active unit. If the state and inputs are the same, then the outputs should also be the same. If the outputs fail to match, either the off-line or the active unit has failed. Comparing the off-line unit with a different active unit indicates which has failed. This technique is useful in a system where there are several copies of a particular circuit. Only one additional copy plus some comparison circuitry must be added.

The third technique involves software controlled testing of the hardware. The CCU will periodically test out its own components by running diagnostic software. The CCU will also check out the hardware fault control circuits, such as parity checkers and comparator, by inducing errors and watching for an error indication. For example, if a parity error is induced but no parity error was indicated, then the parity checker has failed.

For fault correction purposes, hot standby units are provided in all for N redundancy configuration. This means that for every N circuits, which must be identical, one spare is provided which can be substituted for any one of the N circuits. Note that this spare can be used to perform the off-line comparison function described above. For a given number of circuits, N, the reliability can be increased by going to a 2 for N or greater degree of redundancy.

G.3.3.2 Software Failures

Software failures differ from hardware failures in that only the first failure phase is present. Actually, only design errors are significant because manufacturing (i.e., duplication) errors are rare and easily detected. Hence, fault control techniques for software are aimed at detecting and isolating their impact on the system.

Each routine checks its inputs for validity. This is called the principle of mutual suspicion because each routine assumes that all others are faulty. This will detect many faults and prevent them from spreading further through the system. Inputs to a routine include arguments returned to it by a routine which it calls, and information received from the outside world.

Another aid to software fault detection is to complete conditionals. This means that when a variable is tested for different values, all possible values are caught by some test. For example, if a variable can take on values from one to five and one of five different actions is taken depending upon the value, an additional test is added to check for a value greater than five or less than one. The purpose is the same for validating inputs, but in this case, the variable being checked may be used solely within a routine.

To help prevent improper connections from being made due to software errors, a CCU lockout feature is provided. This is hardware implemented and, when activated, it blocks the flow of commands from the CCU to the other DCE elements. It is activated when a software error is detected or when parity error is detected ina command from the CCU. It cannot be deactivated by the CCU, but requires human intervention to allow the CCU to continue control of the DCE.

6.3.4 Initialization and Recovery

To initialize and bring up a DCE, the software at the NCS must first be installed and the data base generated. After power is applied to the DCE, the RESTART button is pressed which causes a RESTART interrupt. The CCU initializes itself and requests that the system tables be loaded. After they are loaded, the CCU is ready to accept a LOAD command to initialize the address memories which starts the flow of information through the DCE.

Recovery from a power failure does not involve human intervention. When power returns, the CCU automatically intitalizes itself and reloads the address memories. It then continues processing where it left off when the power failure occurred. Note that this requires a battery backup for the CCU RAM. If this is not provided, then a manual RESTART must be performed. Recovery from a CCU hardware or software failure requires a RESTART cooperation. The address memories should be reloaded in case the connections were made improperly by the CCU prior to detection of the error and the subsequent activation of the CCU lockout.

In the event that the CCU is isolated from the NCS (e.g., the station telemetry system fails), the DCE will operate in a fall-back mode. The station controller, via the Controller Terminal Function, or local backup terminal,

can still command the DCE to alter the channel connectivity, but now he must use connection addresses instead of the formal format (e.g., TFELM029801112, which indicates direction, site, link, supergroup, group, and channel). He can perform the traslation by calling a node on an orderwire and having personnel at the node access the data base and return the result to him. Alternatively, each site could have a listing of the connection address/channel mapping, which is periodically updated. All connectivity changes made during this fall-back condition are saved by the CCU on a list. When communications between the NCS and DCE are restored, the NCS uses this list to update its data base.

G.4 Synchronization

A description is provided of the methods and algorithms that the DCE employs in order to synchronize the channel reassignment function so as to maintain BCI in all channels. Master frame synchronization is discussed only with respect to DRAMA equipment. The algorithm used to synchronize the digital groups received from AUTOSEVOCOM II and TRI-TAC is the same as that specified in TRI TAC document ICD-003 and therefore, will not be discussed. DNC timing results are based on the availability of an accurate and stable DCS timing reference.

G.4.1 Master Frame Synchronization

This section describes the algorithm used by the Input Framing Unit (IFU) to setablish and maintain master frame synchronization in each T1 digital group received from a TD-1192, TD-1193, or another DCE. The algorithm is designed for a random error environment of no more than 1 error per 1000 bits.

The algorithm operates in two modes, frame maintenance and frame acquisition. In the frame maintenance mode, the IFU assumes that it is in-synchronization and monitors the receive direction for loss of synchronization. In the acquisition mode, the IFU assumes that it is out-of-sychronization and monitors the receive direction for the correct synchronization position. If the IFU is in the maintenance mode and determines that it has lost synchronization in a particular digital group, it switches to the acquisition mode for that group. The IFU returns to the maintenance mode only after it determines that it has relocated the correct synchronization position.

In each mode of operation, a 16-bit sync word is formed using 16 consecutive bits from the assumed synchronization position. If the IFU is in synchronization and neglecting the occurrence of bit errors, the correct sync word consists of either the 1010...10 pattern or the 0101...01 pattern. If the IFU is out-of-synchronization, the sync word consists of a random string of 16 bits. Each time a complete sync word is formed, it is correlated against one or both ocrrect sync word patterns, depending upon the IFU mode. If the IFU is in acquisition mode, both correlations are performed and the following rules apply:

a. If either correlation results in no disagreements, declare an in-sync condition, flag the framing bit position and the correct sync pattern, switch to the maintenance mode, and check the next sync word for frame maintenance.

b. If both correlations result in at least one disagreement, remain in the acquisition mode, displace the synchronization position one bit, and check the next sync word for frame acquisition.

If the IFU is in the maintenance mode, the correlation is performed against the last correct sync pattern and the following rules apply:

a. If the correlation results in three or fewer disagreements, remain in the maintenance mode and check the next sync word for frame maintenance.

b. If the correlation results in four or more disagreements, declare an out-of-sync condition, switch to the acquisition mode, displace the synchronization position one bit, and check the next sync word for frame acquisition. When switching from maintenance to acquisition, the acquisition mode first checks ± 2 bits from the last correct synchronization position per DRAMA equipment specifications.

Th algorithm just described results in the synchronization performance shown in Table G-1. Each performance category meets or exceeds DRAMA specifications.

TABLE G-1. DCE T1 FRAME SYNCHRONIZATION PERFORMANCE

A.	FRAME ACQUISITION	PERFORMANCE
	I. Start-Up	
	1. Time to Acquire	50 msec
	2. Probability of Acquiring	.98
	3. Probability of False Acquisition	.02
	II. Following Loss of BCI (± 2 bits)	
	1. Time to Detect and Reacquire Sync	8 msec
	2. Probability of Acquiring Sync	.98
B.	FRAME MAINTENANCE	
	1. Mean Time to False Loss-Of-Sync	39 Hours

G.4.2 DCE Timing

The DCE will provide group buffers within the IFU for each terminating digital group. These buffers compensate for transmission delay variations and timing differences between the DCE master timing unit and the recovered clock for each digital group.

Estimates of the effects of transmission delay variations are discussed below:

a. Coaxial Cable

1. The dominant cause of delay variations is linear expansion caused by temperature change.
2. Changes in transmission delay occur slowly.
3. For a path length of 3000 miles and a transmission rate of 1.544 Mb/s, the change in the number of bits stored in a cable due to a $22^{\circ}C$ temperature change is approximately 10 bits.

b. Microwave Radio

1. Delay variations are caused by changes in temperature, pressure humidity, and rain.

2. Rapid and long-term delay variations are possible.

3. Average variations in link bit storage are daily, 0.5 bits; monthly, 2.5 bits; and yearly, 7.5 bits.

c. Troposcatter Transmission

1. Short-term variations are to be expected; however, significantly greater than those experienced in LOS radio links.

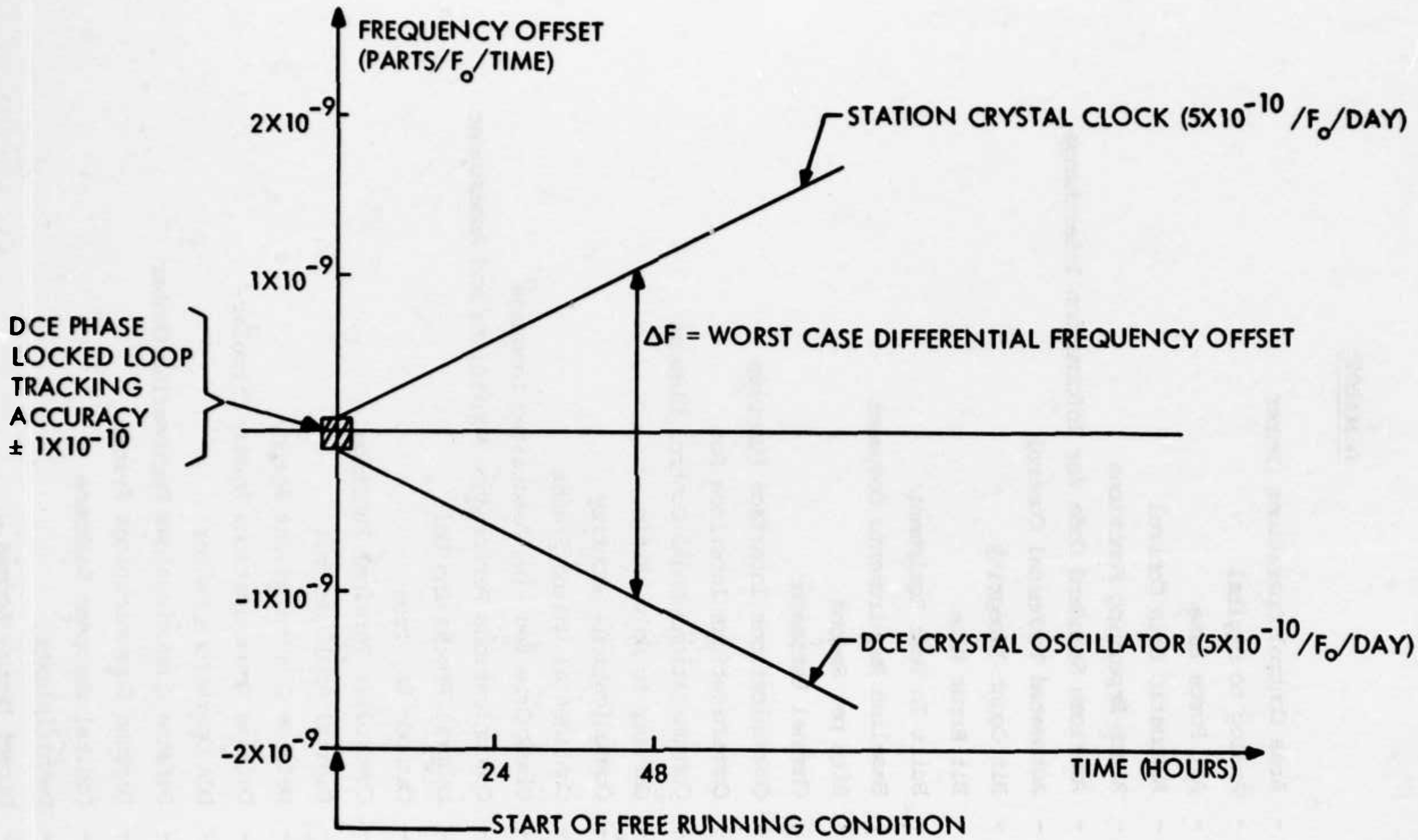
d. Satellite Transmission

1. Delay variations in a satellite link during a 12-hour period can be quite severe, due primarily to orbital eccentricity. Buffer requirements for such links on the order of 5000 to 6000 bits are possible. However, this buffering is provided by the satellite ground station and need not be considered a DCE requirement.

Based on the above estimates of delay variations, 20 bits of capacity will be allocated to transmission delay variations in each digital group buffer.

The buffer capacity required to compensate for timing differences is determined for the situation in which the DCE is isolated from the station timing supply and the station timing supply is isolated from its DCS master. It is assumed that both timing supplies employ crystal oscillators instead of atomic clocks. Designing to this worst-case situation ensures that sufficient buffer size is allocated. The required buffer to provide a 24-hour free run capability for DCE is 186 bits. The details of the calculations are shown in Figure G-7. The clock stabilities shown in this figure are conservative values based on commercially available crystal clocks.

It follows from the results of this section that the total capacity of each digital group buffer must be at least 206 bits, 20 bits from transmission delay variation compensation and 186 bits for clock difference compensation.



BUFFER REQUIREMENT FOR 24 HOURS $= 2 \times \int_{0}^{86400} \Delta F \, dt = 186$ BITS

NOTE: TRANSMISSION RATE = 1.544 MB/S

FIGURE G-7. MASTER TIMING UNIT BUFFER REQUIREMENTS

ACRONYMS

ACOC - Area Control Operations Center
A/D - Analog to Digital
AFB - Air Force Base
AGC - Automatic Gain Control
ARF - Alarm Reporting Functions
ASCII - American Standard Code for Information Interchange
ATEC - Automated Technical Control
BCI - Bit Count Integrity
BER - Bit Error Rate
BITE - Built In Test Equipment
BLRD - Baseline Requirements Document
B/S - Bits per Second
CE - Channel Estimator
CIF - Communications Interface Function
CIS - Communications Interface Set
CNCE - Communications Nodal Control Element
CNR - Carrier to Noise Ratio
COMSEC - Communications Security
CONUS - Continental United States
CORAL - Class Oriented Ring Associated Language
CPMAS - Communications Performance Monitoring and Assessment
CPU - Central Processing Unit
CRT - Cathode Ray Tube
CTF - Controller Terminal Function
DAU - Digital Applique Unit
DCA - Defense Communications Agency
DCAC - Defense Communications Agency Circular
DCAOC - DCA Operations Center
DCEC - Defense Communications Engineering Center
DCS - Defense Communications System
DEB - Digital European Backbone
DEMUX - Demultiplexer
DMA - Direct Memory Access

DOD	-	Department of Defense
DRAMA	-	Digital Radio and Multiplexer Acquisition
EFS	-	Error Free Seconds
EFS/B	-	Error Free Seconds/Blocks
FDM	-	Frequency Division Multiplex
FKV	-	Frankfurt-Koenigstubl-Vaihingen
FM	-	Frequency Modulation
HAZCON	-	Hazard Condition
HOL	-	Higher Order Language
IF	-	Intermediate Frequency
I/O	-	Input/Output
ISI	-	Intersymbol Interference
KBD	-	Keyboard
KDU	-	Keyboard Display Unit
KG	-	Key Generator
LK	-	Link
LMS	-	Least Mean Square
LO	-	Local Oscillator
LOS	-	Line of Sight
MAS	-	Measurement Acquisition Subsystem
MB/S	-	Megabits per Second
MBS	-	Mission Bit Stream
MDTS	-	Megabit Digital Troposcatter System
MPT	-	Mean Prediction Time
MSE	-	Mean Square Error
MTBF		Mean Time Between Failures
MTBR	-	Mean Time Between Repair
MTBUF	-	Mean Time Between Unpredicted Failures
MTTR	-	Mean Time To Repair
MUX	-	Multiplexer
NCS	-	Nodal Control Subsystem
OW	-	Orderwire
PA	-	Power Amplifier
PCM	-	Pulse Code Modulation
PR	-	Partial Response

PS - Power Supply
PSK - Phase Shift Key
QAM - Quadrature Amplitude Modulation
RADC - Rome Air Development Center
RF - Radio Frequency
RSL - Received Signal Level
RX - Receiver
SC - Subchannel
SCBS - Service Channel Bit Stream
SCA - Sector Control Subsystem
SDR - Signal to Distortion Ratio
SG - Supergroup
SNR - Signal to Noise Ratio
SYSCON - System Control
TBD - To Be Determined
TCCF - Tactical Communications Control Facility
TDM - Time Division Multiplex
TED - Trunk Encryption Device
TFD - Transmitter Frequency Drift
TSP - Transmitted Signal Power
TX - Transmitter
U/C - Up Converter
VDU - Visual Display Unit
VF - Voice Frequency
VOW - Voice Orderwire
VSWR - Voltage Standing Wave Ratio
WDMF - Wideband Digital Measurement Function
WDMS - Wideband Digital Monitoring Set
XPD - Cross Polarization Distortion

MISSION
of
Rome Air Development Center

RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

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7